Seed System Development

The Appropriate Roles of the Private and Public Sectors

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Jitendra Srivastava
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(Continued on the inside back cover.)
Seed System Development

The Appropriate Roles of the Private and Public Sectors

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The World Bank
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Agricultural support services, such as seed production and distribution activities, are an essential element of agricultural development because they can greatly influence the sector's level of productivity. As the food requirements of growing populations escalate, compounded by the need to generate highly valued foreign exchange, increasing agricultural productivity will continue to be a vital national concern in developing countries. In the past, a major component of government strategies for ensuring growth in agricultural output has been public provision of agricultural support services. Recently, however, as countries have struggled to achieve higher levels of economic efficiency— and spurred by growing fiscal deficits and pervasive organizational inefficiencies—governments have had to reconsider such strategies. This development has also highlighted issues regarding the potential role of the private sector in the delivery of these services.

This study was initiated in response to the need to understand the appropriate roles of the public and private sectors in the delivery of agricultural support services. It is one of a series of studies focusing on this issue—the others discussing public and private sector roles in livestock services, agricultural research, and agricultural extension. The present study analyzes the economic nature of each of the operating functions which constitute seed production and distribution, including applied plant breeding, seed multiplication, seed storage, transport, and processing, quality control, and seed marketing and distribution. The results of this analysis are used to develop a framework for establishing the appropriate government and private sector roles in seed supply systems.

A review of worldwide experiences shows varied divisions of public and private sector roles in national seed systems. In the developed market economies, the private sector has played a dominant role in commercial seed production and distribution activities for all types of crops and has gradually assumed a major role in applied plant breeding, particularly for hybrids and specialty crops. The roles of the public sector have been complementary, encompassing the support or conduct of basic research and applied plant breeding for particular crops, support for or provision of quality control services, and the regulation of trading practices.

In contrast, in many developing countries, not only does the public sector continue to play a predominant role in applied plant breeding, but it also retains a major direct role in the production and distribution of commercials seeds for important food and other crops. Overlapping functions, public sector resource misallocations, and competition between public sector, private enterprise, and informal farmer-based seed supply activities are common. Some seed supply functions, due to their public good nature or the externalities, moral hazard problems, and/or economies of scale associated with their delivery, may require some form of government intervention. However, experience has shown that for many of the functions, especially those involving the actual production, processing and distribution of commercial seeds, the regulation, subsidization, or taxation of private sector (including farmer-based) activities are frequently more efficient forms of intervention than direct government delivery or control.

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Table of Contents

Executive Summary vii

I. Introduction 1

II. The Seed System: General Components and Stages of Development 4
   The Seed Development, Multiplication, and Distribution Process 4
   Variety Development, Multiplication, and Distribution Systems 8
   Stages of Seed System Development 9

III. The Seed System: Issues in Economic Organization 12
   Public vs. Private Provision of Goods and Services: General Theory 12
   Informal vs. Formal Seed Production and Supply Sub-systems 16
   Alternative Institutional Arrangements in Formal Sub-systems 20
      Varietal Development (Plant Breeding) 20
      Seed Imports 25
      Seed Multiplication 26
      Seed Processing 28
      Seed Quality Control 29
      Seed Storage 30
      Seed Marketing 31

IV. Public and Private Sector Roles in Seed Industries: An International Perspective 36
   Wheat Seed Industries 39
   Rice Seed Industries 43
   Maize Seed Industries 46
   Vegetable Seed Industries 50
   Seed Systems in Transition 53

V. Conclusions and Policy Implications 58

Bibliography 70
Appendix: Case Studies of Seed System Development

1. The Seed System of the United States  
2. The Changing Public/Private Mix in the Indian Seed System  
3. Public, Private, and Cooperative Sectors in the Mexican Seed System  
4. Public, Private, and Cooperative Roles in the Zimbabwe Seed System  
5. Expanding the Scope and Impact of the Ethiopia Seed Industry  
6. Specialized Export-oriented Seed Production in the Private Sector  
7. Informal Seed Distribution: An Illustrative Case from Peru
EXECUTIVE SUMMARY

0.1 Seeds are the living organisms which carry the genetic properties of crop plants. Seeds are the single most important input in all plant-based agricultural systems; they determine the upper limit on yield potential and therefore the productivity of other inputs. Fertilizer, pesticides, and irrigation water provide for a good crop only if the plants growing in the field are capable of using these inputs effectively. In addition, improved seed can frequently make a substantial contribution to agricultural productivity and sustainability, at relatively little cost, independent of these other inputs.

0.2 Improved seed represents the outcome of a multiple and sequential series of activities and decisions; the outcome of a process which begins with the initial manipulation of germplasm and identification of a suitable variety or hybrid, continues through the multiplication, processing, and distribution of seed, and ends with farmer up-take and use of this seed. Major functions in this process include varietal development and release, the multiplication of several generations of seed, seed quality control, seed processing and conditioning, seed storage and transport, seed demand assessment and market promotion, and seed distribution.

0.3 In the developed market economies, the private sector has long held responsibility for virtually all seed production, processing, and distribution activities and (for some crops) has gradually assumed a major role in applied plant breeding as well. In the seed industries of these countries, the primary roles for the public sector have been the support or conduct of basic research (and applied plant breeding for particular crops), support or development of seed crop inspection and seed certification services, enforcement of plant variety protection statutes, and regulation of fair trading practices. A complementarity between private and public sector roles has been an important factor in the technical and commercial progress of these countries' seed industries and their ability to respond to changing market requirements.

0.4 In contrast, in most developing countries as well as in the former Eastern European socialist countries, formal seed industries are characterized by a major, if not exclusive, role for public sector institutions. Over the past two decades, many developing countries (frequently with the assistance of international development agencies) have invested in large-scale national and provincial seed enterprises
and in government seed farms. While ideological considerations led to the development of public seed systems in some countries, investments in public sector seed production and distribution in other countries were stimulated by immediate food security pressures and a lack of confidence in the capacity of farmers or a nascent private sector to meet national seed requirements for major crops.

0.5 While many public sector supply systems have expanded domestic seed output and while some public seed enterprises have played an important role in the initial spread of high-yielding varieties (or hybrids) of rice, wheat, and maize, most such enterprises have operated at well below their operational capacity, have been a major financial liability for their governments, and have often produced substandard quality products. Influenced by political pressures and hampered by limited technical and managerial capacities, none of the public seed enterprises have been able to meet the diverse crop and varietal needs of different categories of seed users in their countries.

0.6 Until recently, little attention was given to the potentially important roles which private firms, cooperatives, other non-governmental organizations, and farmers might play in seed supply systems, with private sector participation actually being barred in some countries. However, budgetary pressures, together with concern about the inefficiency and ineffectiveness of public seed enterprises and the increasing demand for high-quality seeds, are leading many developing country governments (and international development agencies) to reconsider the roles of both the public and private sectors in seed supply systems.

0.7 This paper analyses the economic and institutional factors affecting the appropriate roles for the public and private sectors in seed supply systems, examines the current mix of public and private sector seed activities world-wide, and traces changes in the structure and operation of national seed systems in selected industrialized and developing countries. By defining the scope for private sector involvement in seed development and supply activities as well as the critical and complementary roles for the public sector in the development of efficient seed systems, this paper seeks to contribute to the design of improved strategies for seed system development in developing countries and in formerly centrally planned countries.
Economic theory provides some guidance regarding the appropriate roles of the public and private sectors in seed supply systems. By applying concepts from welfare economics to the major functions of seed development, production, and distribution, it is possible to discern whether the private sector will have an incentive to perform the functions, whether private provision of such functions is likely to be at socially optimal levels, and the areas in which government interventions can be justified on economic grounds. As the major functions associated with seed development, production, and distribution have different economic attributes, it is important to examine the incentives for private sector involvement and the justification for public sector intervention for each function separately.

**Varietal Development**

The development of new varieties and hybrids can be a profitable activity for private firms, either specialized R&D firms or firms which also engage in seed production and distribution. However, for several reasons the amount of investment in these activities by the private sector may not reach socially optimal levels. First, private firm entry into plant breeding may be constrained by the high costs and risks, the long gestation periods, and the high technical, capital, and human resource requirements of such work. This may limit the extent of competition in this activity. Second, there are potentially significant externalities associated with effective plant breeding work (and germplasm and varietal maintenance) for which the breeder may capture little or none of the benefits and therefore not take into account when making investment decisions. Third, many outputs from plant breeding R&D have the public good properties of non-exclusivity and non-rivalry— it is often difficult or costly to prevent non-paying farmers or firms from benefitting from the knowledge embodied in new varieties of seed and many such individuals can simultaneously use this knowledge without depleting it.

The significance of these factors varies across different types of crops. In the case of hybrids, plant breeding work is technically demanding, very costly, and a long-term venture, generating considerable technical and financial barriers to entry. However, for those private firms able to marshall the requisite resources, plant breeding of hybrids can be commercially attractive given the biological protection which plant breeders obtain over their R&D output by maintaining control over the inbred lines. In contrast, varietal development work for self-pollinated varieties (e.g. of rice and wheat) is rather conventional (presenting less significant entry barriers), yet the scope for the breeder to appropriate the benefits from such R&D may be very limited since its output can be easily exploited by others. In the
absence of plant variety protection (and enforcement), private investment in such activity will be very limited and public sector financing or direct performance of this function will normally be required.

**Seed Production**

0.10 The production and processing of seed also features externalities, risks, significant skill requirements, and 'public good' characteristics, although their magnitude is considerably less than in the case of varietal development work. The economic and technical barriers to entry for the private sector in these activities are thus far lower than for varietal development. Over a wide range of production and processing activities there is ample scope for private suppliers to appropriate a sufficient proportion of the benefits to make such investments profitable.

0.11 Where market demand for commercial seed is developing, opportunities for profitable production of hybrids and multiplication (and processing) of improved open-pollinated varieties (e.g. maize), and of seeds of specialty, high value crops (e.g. horticultural crops) may be significant. In all such cases, it is very difficult and/or costly for farmers to produce and save high quality seed on their own. Due to the moderate to rapid loss in genetic and/or physical purity, use of farmer-saved seed for such crops will result in yield losses. Potential profit margins are comparatively much lower for the multiplication and processing of seeds for self-pollinated crops, since specialized producers will have to 'compete' with farmer seed retention. Only (small) firms which carry very low overhead costs yet are able to produce seeds of consistently high quality might be expected to profit from such activities. To achieve this, such seed multipliers would need to acquire improved varieties from public or private plant breeders at relatively low cost.

Direct public sector production of seed can be justified in the case of foundation seed for self-pollinated crops as this activity is generally unprofitable and is associated with significant externalities. As the foundation seed will be planted over a potentially wide area to produce commercial seed, the loss of genetic or physical purity in the foundation seed will have adverse effects on the subsequent production of commercial seed, on seed marketing efforts, and on farm-level productivity. Once foundation seed is available, the private sector can take responsibility for the production of commercial or certified seed.

**Seed Processing**

0.12 Seed processing is frequently the component of the production-distribution process which requires the largest capital investment. This is because some seed drying, cleaning, chemical treatment, and
packaging activities either require or are more efficiently performed with mechanized equipment. This does not mean that large-scale processing facilities are required, only that some minimum scale should be attained for maximum efficiency. The technical difficulty of seed processing varies among crops, being relatively easy for most field crops and considerably more difficult for most vegetable, oilseed, and forage crops.

There is little economic justification for direct public sector involvement in seed processing except where economies could be gained by integrating processing activities with existing public sector seed multiplication activities. As long as the necessary technical skills, financing, and capital equipment can be acquired, seed processing can be a value-adding activity for private seed producers or traders or a profitable activity for private firms specializing in this activity.

Seed Marketing, Distribution, and Quality Control

0.13 In an environment where purchase prices for seeds are largely market determined and where a significant proportion of agricultural production is for commercial purposes, most of the functions which constitute seed marketing and distribution (e.g. market research, demand promotion, seed storage, transport, and distribution) can normally be performed profitably by the private sector. It is particularly in this line of activities, where flexibility of action and responsiveness to market demand are important criteria for success, that the private sector has its greatest potential advantages over the public sector. Nevertheless, because the performance of several such functions is associated with economies of scale, externalities, and informational (product quality) problems, private sector investments may remain below the social optimum and may result in problems of equity in seed distribution.

0.14 For example, economies of scale (and scope) can be realized in market research, demand promotion, and, to a more limited extent, in seed storage and transport. This condition could lead to barriers to entry or competitive disadvantages for small-scale enterprises and to the possible concentration of the industry. This condition may also lead private firms to refrain from serving relatively small or isolated market areas. Hence, some farmers may be poorly served by private seed distribution channels or face non-competitive prices for commercial seeds.

0.15 Second, the promotion of seed demand features potential externalities since widespread farmer uptake of improved commercial seeds may generate social benefits of greater magnitude than the private benefits obtained by individual farmers and the added profits obtained by seed distributors. The spin-off
effects on local services and agro-industries will not be taken into account when a private firm considers its potential returns from promotional activities. At least supplemental public sector promotion of the adoption of improved varieties can be economically justified.

0.16 Third, because many of the important quality attributes of seeds cannot be easily observed or measured prior to actual planting, there is the potential for seed promoters and distributors to profit, at least in the short-term, by misrepresenting the quality attributes of their seed. The result of such private actions may be unnecessary costs and even crop failures for farmers and an overall reduction in confidence in the value of commercially-supplied seed. While competitive pressures can marginalize opportunistic peddlers of low-quality seeds, such competitive pressures may be weak. In any case, market development can be strengthened by the implementation of seed standards, of systems of seed evaluation and certification, and of sanctions against traders who misinform customers. The public sector will normally have a comparative advantage in the enforcement of such regulations.

0.17 Hence, an analysis of the technical and economic characteristics of seeds and of seed production, processing, and marketing functions indicates complementary roles for the public and private sectors. The production, processing, and distribution of many types of seed can be profitable for the private sector, provided that improved germplasm or varieties are available and demand exists (or can be stimulated) for commercially supplied seeds. The private sector may also be in a position to profitably undertake R&D work related to hybrid or varietal development. While an economic rationale for direct public sector participation in seed production and distribution is limited to a few areas (e.g. breeder and foundation seed production for self-pollinated varieties; storage of limited foodgrain seed stocks), the public sector has a very important role in supporting (or directly undertaking) basic and applied R&D work, in promoting seed industry entry and competition, in implementing quality standards, in promoting farmer adoption of improved seeds, and in compensating for externalities and information-related problems in seed production and trade.

Actual Public and Private Sector Roles in Advanced Market and Developing Countries

0.18 A survey of seed and agricultural specialists at the World Bank and within the CGIAR network, private sector, and academic community, together with a seed industry literature review was undertaken in order to identify the actual mix of public and private sector activities in seed systems worldwide and
to trace changes in institutional structures as national seed systems have developed. The survey found that in the seed industries of advanced market economies, the present mix of public and private sector activities is largely consistent with the guidance or predictions of economic theory. In contrast, in many developing countries, the public sector remains heavily involved in direct seed production and distribution, sometimes in the place of or in competition with the private sector. The paper presents information on the institutional structures for seed systems in twenty-five countries for wheat, rice, maize, and vegetables.

0.19 The survey indicates that varietal development work is undertaken by the public sector (e.g. research institutes and universities) throughout the world. The public sector plays an exclusive role in plant breeding R&D for self-pollinated crops such as rice, wheat, and barley in most countries. The major exceptions to this pattern are in Argentina, Chile, and several industrialized countries where the private sector has undertaken plant breeding work geared toward the hybridization of wheat or rice and the generation of varieties suitable for very specific agro-ecological areas. The public sector is also widely involved in basic research and germplasm collection, evaluation, and enhancement—the building blocks for commercial varietal and hybrid development.

0.20 Both in industrialized and developing countries, private sector plant breeding R&D has been heavily concentrated on hybrids for major food, industrial, and horticultural crops, with the development of hybrids for maize receiving the greatest attention and resources from the private sector. As a result of the high costs and technical demands of plant breeding work, most of the private firms active in this work are large in scale and also active in downstream seed production and sales. In many developing countries, much of the private sector activity in this area involves multinational corporations or joint venture companies.

0.21 Private sector involvement in seed production and processing is more extensive and features firms with more varied size and ownership characteristics. In the advanced seed systems of North America, Western Europe, and Japan, the private sector, comprised of large companies, cooperatives, and small, localized companies, dominates seed production and processing for the full range of crops, although in some countries (especially the United States) farmer-retained grain provides a large proportion of the seed used in small grains production (e.g. wheat, oats, barley). While larger companies have
focused on hybrids and specialty crop seeds, seed multiplication for (public sector-bred) self-pollinated varieties has been undertaken by cooperatives, small companies, and specialized seedsmen.

0.22 Among developing countries, the leading and sometimes dominant seed producers are farmers themselves, with farmer-saved seed and seeds from other farmers accounting for 80% or more of the seeds used in many developing countries. Farmer-saved seed is dominant not only in those countries where the introduction or local development of hybrids or improved varieties has remained very limited (e.g. in much of sub-Saharan Africa), but also in several countries with more advanced formal seed development and supply systems (e.g. Mexico, India, and Thailand). Such patterns dictate that farmers be viewed as core participants in national seed systems rather than simply as consumers of the output of such systems. Improving the linkages between formal systems of plant breeding R&D, seed production, and seed distribution and informal farmer and community-based seed supply arrangements is thus a major challenge.

0.23 While in a few developing countries, seed production within formal seed industries is undertaken almost exclusively by either the private sector (e.g. in Argentina and Chile) or the public sector (e.g. in China), the typical institutional pattern is one of a mixture of public and private sector activities. Public sector involvement is most widespread and intensive in the production of high-volume self-pollinated crops, such as rice, wheat, barley, and various legumes, and of open-pollinated varieties of maize. Since such seed accounts for a large majority of the volume of formal seed production in most developing countries, public seed enterprises continue to account for a majority of total seed production among developing countries. However, while public seed enterprises or research institutes in many countries do directly produce foundation seed for such crops, the production of commercial seeds for these crops is more commonly contracted out to farmers or cooperatives. While the public enterprises bear the market risk for such seed and frequently provide financial and/or technical backing for such production, the actual seed multiplication is done by farmers. Only in a small number of countries (including Egypt, Turkey, Ethiopia, Nigeria, China, Indonesia and Bangladesh) does a large proportion of commercial seed multiplication of self- and open-pollinated varieties occur on state-owned farms. In most cases, these are loss-making operations.

0.24 In several developing countries, public seed enterprises have also entered into the production of selected hybrid and specialty crop seeds, sometimes in competition with the private sector. Public sector entry into such activities has been driven by various factors, including government concern about the
development of 'strategic' export or agro-industrial sectors, an objective of cross-subsidizing losses from the production of low-value seeds of self-pollinated varieties, and a perception that the nascent private sector is developing too slowly to effectively spread hybrids and improved varieties. However, in the majority of cases where commercial markets for such seed have developed and where public sector monopolies were not imposed (or maintained), it has been the private sector or joint venture enterprises which have emerged to account for dominant shares of local production.

0.25 The private sector plays a dominant role in seed marketing and distribution within advanced market economies, with government intervention being confined to the enforcement of standards and truth-in-labelling. In contrast, in most developing countries, seed marketing and distribution features a mixture of public and private sector participation. For self-pollinated staple food crops, public seed corporations continue to play major roles in seed storage and wholesaling and in seed promotion in many countries. In some countries (including Mexico, Egypt, Nigeria, Syria, Ethiopia, and China), public institutions also supply such seeds directly to farmers, either through credit agencies or special agricultural projects. This seed is usually subsidized by government. Nevertheless, in most countries, small private firms and cooperatives have been able to compete with public seed distribution as a result of their willingness to earn low margins, their access to both public and private varieties, their provision of additional services, and the uneven or low quality of seeds supplied by some public seed companies.

The distribution of hybrid, horticultural, and other specialty seeds also features a mix of public and private sector activities in most developing countries, although the private sector frequently accounts for dominant market shares. In many developing countries, seeds (or other planting materials) for industrial and export crops are distributed in part or solely by the major processing or commodity trading firms. Continued direct public sector involvement in seed distribution for such crops even after the private sector has developed has frequently stemmed from a strategy to cross-subsidize public enterprise losses from distributing high volume/low value self-pollinated seeds. Such public sector involvement in high-value seed markets reduces demand for private seed.

Policy Implications

0.26 There is no ideal institutional structure for a seed system. The most efficient mix of public and private activities varies among countries, types of crops, and stages of seed system development. Both the public and private sectors have important roles, yet there are substantial limitations on what each can do separately. The privatization issue is therefore not whether the private or public sectors are 'better' (e.g. more cost effective) at supplying a certain set of services, but how the two sectors can best
complement one another in providing the entire set of services related to seed development, production, quality control, and distribution. Any process of seed system privatization must proceed with a recognition of the differential incentives for private sector participation in various activities and of the required role for the public sector, both during the privatization process and once private seed development, production, and distribution activities are well established.

0.27 Where privatization is adopted as a central strategy to improve seed system performance, it must be recognized that the private sector consists of many different types of entities, each with different objectives, capabilities, and limitations. For example, international seed companies will be attracted to markets for hybrid and high-value specialty crop seeds, but not for seeds for many high-volume and low profit margin staple food crops. Frequently, their initial focus will be on supplying seed to the more commercialized large farm sub-sector. In contrast, many local firms may focus on seeds for staple food crops, yet lack the financial and technical capacities to conduct their own R&D activities or to engage in seed distribution over a broad geographical area. In promoting seed system development, a legal and economic environment should be created to allow a broad range of institutions and participants to develop which, together, can meet the diverse seed requirements at national and local levels. Hence, policies and programs should be designed which will induce investments in 1) informal, village-level seed production and exchange operations, 2) small-to-medium-scale private local companies, 3) large local, foreign, or joint venture companies, and 4) seed associations and cooperatives.

0.28 Experience from many industrialized and developing countries indicates that public research (including that of the international research centers) and public support for private sector plant breeding R&D, seed multiplication, and seed marketing can lead to efficiency gains. This is especially the case in the early stages of seed system development when the supply of improved germplasm and of trained seed technicians is inadequate, the financial resources available for research and infrastructure development are very limited, and there is limited information about potential seed demand. At such early stages, the public sector will need to initiate or support plant breeding R&D activities and produce breeder and foundation seed. It can support nascent private sector development by making the foundation seed widely available, by providing financial and technical backing to seed multiplication pilot projects and to firms seeking to manufacture seed processing equipment, by training seed technicians, by encouraging the formation of seed producing associations or cooperatives, by instituting national seed policies, seed quality standards, and quality control programs, and by actively promoting the adoption by farmers of new crop varieties.
0.29 At later stages in seed system development, the nature of public sector support and regulatory measures should change in line with the changing needs of the emerging industry and of farmers. For example, the public sector can further stimulate private plant breeding R&D by providing enhanced germplasm and technical training, by facilitating the import of germplasm, and by making inbred lines available to private firms. Such efforts reduce the costs of entry for private firms and reduce the time period required for them to develop finished varieties and hybrids. At such stages, government institutions should also promote competition in seed markets, counter informational imperfections, and provide certain other public services. Appropriate public sector functions include providing optional testing and certification of seed for quality, the conduct and publication of results from comparative variety quality tests, the passage and enforcement of truth-in-advertising regulations, the holding or financing of limited stocks of commercial seed to counter seed shortages following a drought or other adverse natural event, the collection, processing, and distribution of information pertaining to commercial seed demand, the facilitation of access to credit (and foreign exchange) for seed enterprises, and the promotion of foreign investment in domestic seed systems.

For equity reasons or in pursuit of other objectives, governments may also subsidize the distribution of seeds in relatively remote or sparsely populated areas. Otherwise, seed subsidies are not necessary. Not only do the costs of seed comprise a very small proportion of total production costs for most crops, but the available evidence indicates that farmers are willing to pay commercial prices for seed which is of truly superior quality. As long as competition within seed distribution can be maintained, a direct public sector role in such distribution is unnecessary.

0.30 Dissatisfaction with the past poor performance and financial losses of public seed enterprises in developing countries and centrally planned economies must not lead to the wholesale scrapping of such organizations and attempts to construct a private sector upon the wreckage. In many countries, public seed enterprises will indeed have to be restructured with perhaps a considerable rationalization of personnel and infrastructure. However, in many cases it may be both cost effective and politically expedient to maintain certain components of these seed enterprises as nuclei for public sector support and coordination of private sector seed production and distribution activities. Initial privatization efforts might focus on the contracting-out of some or all of the production and distribution functions of such enterprises and on developing units within these enterprises to channel technical and other means of support to emerging private firms. Over the longer run, the development of a well-functioning private seed industry will depend upon well-functioning complementary public sector agricultural research, information, and trade regulatory services.
I. Introduction

1.1 In the context of agriculture, seeds can be broadly defined as all living materials used to plant a crop. Seeds are the living organisms which carry the genetic properties of crop plants. For some crops, including wheat, rice, maize, and most vegetables, the genetic information is carried within dry seeds. For other crops, including cassava, sugarcane, bananas, and some cut flowers, the 'seeds' used are actually cuttings of tubers or other vegetative part of the plant which is detached and then replanted to grow another plant.

1.2 Seeds have the unique characteristic of being both an agricultural output and an input. Seeds are an agricultural output in one period, produced either by specialist producers or on the farm where they are used, which then become a farm input in a subsequent period (Godden (1984). For some crops (including maize, wheat, and potatoes), the seed is actually the edible part of the harvested crop. The producer thus faces the choice of either consuming or selling the 'seed' as a commodity or using or selling it as a production input.

1.3 Seeds are the single most important input in all crop-based agricultural systems. Seeds determine the upper limit on yield and therefore the ultimate productivity of other inputs (Cromwell (1990). While seeds are the carriers of the genetic potential of the crop plant, other inputs simply build the environment enabling the plant to perform productively. No amount of fertilizer, pesticides, and irrigation water will provide a good crop if the plants growing in the field are not capable of exploiting these inputs effectively. Improved seed can frequently make a substantial contribution to increasing productivity in agriculture, at relatively little cost, independent of these other inputs (Lipton and Longhurst (1988).

1.4 Traditionally, farmers grew and maintained their own seeds, selecting from among local landraces and taking advantage of natural outcrosses and mutations in plants. Such selection processes resulted in the development of locally adapted varieties providing reliable performance patterns. The benefits from such seed selection and maintenance were frequently spread through local communities via farmer-to-farmer exchanges of seed. With the advent of genetic science and systematic plant breeding research, substantial improvements in varietal development have occurred offering the potential for major advances in productivity and product quality. Advances in seed technology (including production,
processing, and storage) also now provide opportunities for improving upon traditional seed production and distribution systems.

1.5 There are two sources of improvement in seeds. One is improving the genetic information contained within the seeds themselves. The process of doing this is called varietal development and the result is improved varieties. Improvements in the seed's genetic make-up may provide the potential for higher yields, greater pest resistance, improved quality of the harvested crop, etc. The second source of improvement in seeds relates to the physical and physiological properties of the seed, including its size, physical purity, storability, and germinability. Such improvements are derived from effective processing, quality control, handling, and storage operations with the result being higher quality seeds. Higher quality seeds provide value through their enhanced performance and their compatibility with other production technologies. Hereafter, improved varieties of seeds and higher quality seeds will be collectively referred to as improved seeds.

1.6 The potential benefits deriving from the spread and use of improved seed are enormous, both for individual farmers and for regional and national economies. Some potential benefits are direct; others constitute the multiplier effects of enhanced agricultural productivity. At the farm level, improved seeds can enhance productivity, reduce risks, and increase net incomes via higher yields, faster maturing crops, greater pest resistance, and/or more nutritious content in food or fodder crops. At the farm and regional levels, the availability of improved seed may facilitate more flexible and diversified agricultural production systems by allowing multiple cropping and by spreading crops to a wider set of agro-ecological or geographical zones. Where the diffusion of improved seeds contributes to increased yields and multiple cropping, greater opportunities for farm and post-harvest employment may be generated. Where improved seeds contribute to higher yields and higher quality crops, both processors and consumers may benefit through more plentiful, lower cost, and higher quality supplies of raw materials and food. The spread of improved seeds may also speed up the adoption of other agricultural production technologies, enhance the economic returns on existing or planned investments in rural and agricultural infrastructure, and, when pest resistant varieties are used, contribute to reduced use of pesticides.

1.7 Actual progress in developing and diffusing improved seeds has been quite mixed with most of the potential benefits being unfulfilled in many developing countries. There has been considerable success in introducing and spreading improved cereal and horticultural crop seeds in developed countries, high-yielding varieties of rice and wheat in the irrigated areas of Asia and Latin America, and improved
planting materials for major export crops (e.g. tea, oil palm, rubber) in several developing countries. However, in many developing countries, the development or adaptation of improved varieties of maize, sorghum, millet, cassava, food legumes, vegetable crops, and fodder crops has been very limited, particularly for use in rainfed and upland areas. Even where national or international research centers have made plant breeding breakthroughs, ineffective seed multiplication and distribution systems in many developing countries have limited the spread of improved seeds at the farm level, especially among small-scale farmers.

1.8 In the developed market economies, the evolution of variety development, seed production, and distribution systems has resulted in varied divisions of responsibility between the public and private sectors. In most such cases, however, the private sector has gradually assumed responsibility for most seed production, processing, and distribution activities. Varietal development work has frequently been undertaken by both the public and private sectors, with a division of labor occurring among crops or types of research. In many cases, public sector institutions have remained predominant in basic research, germplasm enhancement, and plant breeding for self-pollinated crops (e.g. wheat, rice, grain legumes) while the private sector has emerged with a preeminent role in R&D concerning specialized crops (e.g. horticultural crops) and hybrid varieties of cross-pollinated crops (e.g. maize, sorghum, sunflower).

1.9 In contrast, in many developing countries, nearly all varietal development work and the bulk of formal seed production, processing and distribution is carried out by public sector institutions and enterprises. Many such parastatal-controlled systems were developed during the 1960s and 1970s with the technical and financial support of international donor organizations (Srivastava (1990)). During that period, either because of pressures to achieve rapid results in the face of food security problems or as a result of the prevailing development philosophies of the implementing governments, little attention was given to promoting comprehensive production and distribution systems including the private sector or other non-governmental agencies (e.g. NGOs) or building upon existing informal, localized seed networks. Many seed projects and national seed programs set out to meet seed production targets, in the absence of an overall seed policy framework and with little assessment of actual seed demand.

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1.10 With a growing realization of the importance of a well-functioning seed sector and concern about
the efficiency of public seed enterprises and the capacity of parastatal-led seed delivery systems to meet
diverse seed requirements, there is now substantial interest in the role which private sector can play in
producing, processing and distributing improved seeds in developing countries, including the role of small
seedsmen and farmer-to-farmer distribution.\(^3\) The objectives of this paper are 1) to examine the scope
for private sector participation in seed development, production, and distribution, 2) to review the
rationale for public sector intervention in seed-related functions and markets, 3) to document the current
mix of public and private sector activities in seed systems world-wide, and 4) to trace the evolution of
seed systems (including the respective public and private sector roles) in selected case study countries.

1.11 The remainder of the study consists of five sections. The following section (Section 2) discusses
major features of the seed development, multiplication, and distribution process and outlines various
stages of national seed system development. Section 3 then examines issues pertaining to the organization
of seed systems, applying principles from welfare and institutional economics. Section 4 then examines
the actual mix of public and private sector activities in the development, production, and distribution of
major types of seeds for a sample of industrialized and developing countries. Section 5 summarizes major
findings and denotes policy implications. Section 6 (Appendix) contains a series of seven case studies
examining the structure and operation of different national seed systems and examining the changing roles
of the public and private sectors in such systems.

II. The Seed System: General Components and Stages of Development

The Seed Development, Multiplication, and Distribution Process

2.1 Improved seed represents the outcome of a multiple and sequential series of activities and
decisions; the outcome of a process which begins with the initial collection and manipulation of
germplasm, continues through the multiplication, processing, and marketing of seed, and ends with
farmer up-take of this seed. The functional process of seed development, multiplication, and distribution
is illustrated in Figure 1 below.

\(^3\) For example, Kelly (1989), Pray and Rubeiro (1990), Cromwell et al. (1990), Echeverria (1990), Srivastava
(1990), Pray and Ramaswami (1991), and Garay et al. (n.d.).
2.2 Seven major sets of functions are indicated in the Figure. The first of these is the process of **varietal development and release**. The major inputs into this process include germplasm, basic scientific knowledge, skilled manpower and research and testing facilities. The actual plant breeding work entails the parental selection and combination of genetic materials through biological or mechanical means. The new varieties which emerge from this work are evaluated for yield and other properties, either directly by the plant breeder, by specialized testing organizations, or by farmers in their own fields. Varieties meeting selected performance criteria are released for a specific agro-ecological area and genetically and physically pure 'breeder seed' is produced. This breeder seed is then the basic input for the subsequent seed multiplication process.

2.3 An alternative to collecting and manipulating germplasm to breed improved varieties is to **import** seed from a foreign producer/supplier representing similar agro-climatic conditions. Such imported seed may be a finished product, suitably conditioned and packaged for direct distribution to farmers or it may be 'foundation seed' requiring further multiplication and subsequent treatment before distribution. Local field evaluation of an imported new variety/hybrid is necessary before seed can be distributed to farmers. Imported seeds must normally be tested (eg. for germinability, purity) and may also be subjected to quarantine regulations to prevent the simultaneous importation of pests and plant diseases.

2.4 The breeder seed of locally-developed improved varieties and the foundation seed of imported seeds must be multiplied in order to obtain quantities of seed sufficient for commercial distribution. The actual number of generations of **seed multiplication** will depend upon such factors as the size of the market for the variety, the required seeding rate, and the average yield for the seed crop. For simplicity, we will consider a three-generation seed production process from breeder to foundation to commercial seed. Commercial seed (sometimes called 'certified seed') must undergo offtype roguing in the field and a degree of processing, perhaps involving drying, shelling, sizing, the removal of inert material and alien seed, and various types of treatment (e.g. fumigation or chemical dressing) to protect seed health and combat against fungi, insects, viruses, and bacteria. Processed seed is normally packed for subsequent storage and distribution.

2.5 **Quality control** functions, including crop certification through field visits and seed testing are important components of the seed multiplication and distribution process. The testing of seed (e.g. for genetic and physical purity, for germinability) normally forms an integral part of the seed multiplication and marketing activities of private and public enterprises. Additional quality screening and control functions may also be undertaken by other institutions. Quality control activities are designed to
Figure 1: The Seed Development/Multiplication/Distribution Process
(Formal System Only)

VARIETAL DEVELOPMENT AND RELEASE
- Germplasm Collection
- Applied Plant Breeding
- Varietal Testing
- Breeder Seed Production/Release

SEED MULTIPLICATION AND PROCESSING
- Foundation Seed Multiplication
- Commercial Seed Multiplication
- Seed Processing and Packaging

QUALITY CONTROL
- Field Inspection
- Testing
- Certification

DIRECT IMPORT OF SEED

STORAGE OF SEED

SEED MARKETING AND DISTRIBUTION
- Seed Promotion/Market Development
- Seed Transport
- Wholesaling

FARMER UP-TAKE OF IMPROVED SEED
identify breakdowns in seed production and distribution operations and to stem the flow of low-quality or alien (e.g. weed) seed through distribution channels and eventually to farmers.

2.6 **Seed storage** is important because seeds, as living organisms, lose their viability if not maintained under proper temperature, humidity, and hygienic conditions. Seed storage is undertaken for several purposes and takes different forms, including long-term storage of breeder seed of certified varieties⁴, the maintenance of reserve stocks of seeds for staple food crops over several years⁵, carry-over seed stocks between crop harvests and subsequent planting seasons, and seed stocks to meet short-term sales requirements.

2.7 **Seed marketing and distribution** involves several different yet closely related functions including: physical logistical operations such as handling and transport, market research, promotional activities such as field demonstrations and advertising, the buying and selling functions associated with wholesaling and retailing, and the related facilitating functions of risk-bearing and financing.

2.8 The above described seed production, multiplication, and distribution functions have social value only if the resultant improved seed reaches farmers and is adopted by them. Farmer demand for any particular variety of seed will be influenced by decisions pertaining to the allocation of land to individual crops and the selection of particular varieties to plant such crops. Such decisions will be based on a multiple set of technical, economic, and institutional factors. For example, farmer decisions on land allocations for individual crops will be influenced by the agro-ecological conditions, expected weather patterns, the availability of labor and other resources, the farmer’s experience and technical know-how, the relative prices and returns of crops, consumption/food security considerations, and the availability and effectiveness of distribution channels for different crops. Factors influencing the farmer’s selection of particular varieties will include the comparative yield and quality characteristics of different varieties, their agronomic properties, their relative commercial values, and the availability of seed. The farmer’s demand for seed can be met either by formal commercial systems of seed production and distribution,

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⁴ Such germplasm and varietal maintenance is important for providing pure parent stocks for future multiplications, for maintaining genetic diversity in local crops, and for providing the genetic materials for future research efforts.

⁵ This serves as a hedge against the risk of severe seed shortages as a result of drought or other natural event.
by informal localized seed supply systems, or by the farmer him/herself by retaining and storing seeds from prior harvests.

**Variety Development, Seed Multiplication, and Distribution Systems**

2.9 The above operational functions are highly interdependent, both technically and economically; the outputs from each activity serve as primary inputs into the subsequent activities. The economic returns to each activity are thus dependent upon the effective performance of other activities. The operational functions are also frequently separated over temporal and physical space. Such features imply that the potential economic benefits from improved seed can be captured only by developing market or other institutional frameworks which effectively coordinate seed development, production, and distribution functions. Such an institutional framework must facilitate the exchange of the physical seed itself, of information pertaining to farmer preferences, overall seed demand, and the availability and properties of supplied seeds, and of financial resources and property rights among seed developers, producers, traders, and farmers.

2.10 The interdependent set of seed-related physical activities, the firms and individuals which perform such activities, and the network of trading and other institutional arrangements which facilitate coordination among such activities and participants can be regarded as constituent elements of national seed systems. Each national seed system is normally composed of numerous sub-systems, geared toward different crops and farmer clienteles. One very important distinction is that between formal and informal seed sub-systems. Formal seed sub-systems typically feature scientific plant breeding work and organized

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6 For example, the benefits from new varietal development are limited by the effectiveness of seed production and delivery operations. The returns to storage operators are limited if transport bottlenecks expose commercial seeds to high temperatures or humidity. Effective marketing campaigns are dependant upon effective quality control measures and appropriate packaging. A highly sophisticated seed quality control service has little value in circumstances where seed processing facilities are poorly designed or maintained.

7 For example, while applied plant breeding research for a variety may extend over several years, the subsequent multiplication and distribution of the finished seed may be confined to one or two seasons. A new variety of seed is normally tested over several seasons before being released for multiplication. On the other hand, once a variety is released, it may be multiplied and distributed repeatedly over many consecutive years. In line with agricultural production cycles, both seed production and demand typically feature a strong degree of seasonality. Some functions may be separated over physical space especially where the targeted market is geographically wide and where seed production and distribution is decentralized among several different participants.
seed multiplication, quality control services, and distribution channels. Government agencies, private firms, and/or cooperatives participate in such systems. Informal seed sub-systems are based on farmer-selected and saved seed and on localized farmer-to-farmer or community-to-community exchanges, sometimes on a barter basis. Formal and informal seed sub-systems may intersect as when farmers periodically draw upon seed or technical information from plant breeding institutions and retailers and then subsequently reproduce the seed over many years. Figure 2 illustrates the distinct and joint contributions of the formal and informal seed sectors to total seed use.

2.11 National seed systems do not operate in a vacuum. The parameters for their operation are set by such elements as: 1) international plant breeding activities and seed markets, 2) the structure of domestic agricultural research, production and marketing systems, 3) agro-climatic conditions, 4) governmental trade, macroeconomic, and agricultural policies, and 5) parallel systems for agricultural extension, credit, and complementary inputs supply. As seed is an input into the production of food, industrial, and other crops, developments in the markets for such crops will strongly influence the need for seed and the profitability of its production and distribution.

Stages of Seed System Development

2.12 Seed systems vary substantially in their institutional complexity and formalization, their degree of commercialization, and their level of technical advancement. The development of seed systems can be visualized as passing through a series of stages (Johnson (1980), although within individual countries, particular seed sub-systems may progress and evolve at different paces and involve different institutional configurations. Four major stages in seed system development can be outlined as follows:

2.13 **Stage One: Sustenance Systems:** At this stage, formal seed breeding and testing programs either do not exist or are very rudimentary, being limited to testing (at research stations) varieties made available by the International Agricultural Research Centers or other countries. Such preliminary R&D programs have yet to develop or identify varieties which are superior to the traditional cultivars. Hence, there is no demand for commercial seed and there exists no 'seed industry' per se. Farmers produce and save all their own seed or procure supplies from nearby farmers or villages.

2.14 **Stage Two: Early Commercial Systems:** This stage begins with the identification of improved (and locally suitable) varieties from external sources or the successful development of improved varieties by
Figure 2
Formal and Informal Sources of Seed

Total Seed Use

Unimproved Seed (Land races)

Own Production & Other Farmers

Formal Seed Sector

Improved Seed

Own Production

Purchased Seed

Informal Seed Sector

Small Seed Growers

Private Firms & Seedsmen

Public Sector
local (public sector) research programs. The successful identification and development of improved varieties presents opportunities for developing a commercial market for seed, although the general outlook of the seed supply organizations typically remains production- rather than market-oriented. At this stage, it is common for public sector or public-sponsored agencies to engage in seed production and distribution for major crops, while an emergent private and/or cooperative sector multiplies and sells public varieties and distributes some specialty crop seeds. Both varietal development work and much of the formal seed production and distribution will be oriented primarily to supplying a limited range of varieties, typically to relatively large-scale, better educated farmers operating in the more favorable agro-ecological zones. At this stage, the broad majority of smallholder farmers typically remain outside of the formal seed system, still relying upon themselves or their neighbors for much of their seed requirements.

2.15 **Stage Three: Rapidly Commercializing and Diversifying Systems:** At this stage, varietal development is broadened to include a wider set of crops and agro-ecological zones, seed production becomes much more market-oriented, and a rapidly growing proportion of seed requirements is accounted for by commercial seeds. At this stage, the private sector begins to play an active role in R&D, particularly in developing hybrids and seeds for specialized cash crops. Nevertheless, the public sector will retain its earlier R&D activities and may even extend them. A growing proportion of commercial seed is produced by the private sector, whether on contract with government agencies or on the account of private firms. At this stage, seed distribution systems become more institutionally varied and decentralized, marketing techniques become more sophisticated, and seed certification systems become well-developed.

2.16 **Stage Four: Mature Seed Systems:** At this stage, both the public and private sectors are active in R&D, while most of the subsequent seed multiplication, processing, quality control, and distribution activities are undertaken by the diverse set of organizations which constitute the private sector. In such seed systems, the institutional arrangements governing seed development, multiplication, and distribution are normally highly diverse. Firms compete among themselves for technological superiority and market share through major investments in facilities, through mergers and buy-outs, through product differentiation, and through the identification and targeting of market niches. At this stage, both consumer and processor/trader interests regarding product quality strongly influence the orientation of seed breeding R&D and the selection of varieties by farmers.
III The Seed System: Issues in Economic Organization

3.1 The development, multiplication, and distribution of improved seeds entails costs as well as potentially substantial benefits to society. The costs include the direct costs of equipment, materials, labor and other resources and the opportunity costs for such resources; the potential benefits include higher yields, better quality raw materials, more nutritious foods, more flexible cropping systems, reduced environmental hazards, etc. The extent to which the benefits from improved seed development and supply exceed the costs involved and how these benefits and costs are distributed determine the incentives and economic rationale for private and public sector investment. This section applies principles of welfare and institutional economics to examine the economic incentives faced by potential investors in seed development, multiplication, and distribution activities. A general conceptual framework is first provided, followed by an application to seed-related activities.

Public vs. Private Provision of Goods and Services: General Theory

3.2 Goods and services can be supplied through two major modes of social organization—The private sector mode uses markets with a variety of private entities making autonomous production and sales decisions based on profit considerations. The public sector mode involves government administration with politically derived rules and procedures determining the allocation of resources. This discussion examines the economic rationale or appropriateness of these two modes of provision.

3.3 The private and public sector supply modes are not as distinct as may at first appear. Even where goods are supplied exclusively by the private sector, the government may play an important supportive or regulatory role by enforcing property rights and standards. When the public sector is the predominant supplier, decisions pertaining to the production and delivery of goods may be influenced by private lobbying groups. Goods produced by the public sector and financed by taxpayers may be delivered by private agents contracted by the government. Hence, in many instances the appropriate question is not whether governments or private entities should participate at all in the provision of goods and services, but what forms such participation should take and what mix of market, administrative, and regulatory mechanisms should guide production and trading decisions.
3.4 One means of assessing the appropriate mix between private and public sector activities is to examine the nature of the goods or services being provided. Products can be classified as either public or private goods. Pure public goods have two properties, commonly referred to as non-exclusivity and non-rivalry. Non-exclusivity refers to a situation where once the good is made available to some users or consumers, it is made available to all other consumers whether or not they pay for it. Non-paying customers cannot be excluded and therefore 'free ride' on the provision of the good. Public goods are non-rival in their consumption and/or supply. Consumption by one individual does not limit the consumption by (and benefits to) anyone else. Once provided to one consumer, the marginal cost of supplying the good to other consumers is zero. This presents problems in pricing the good. A third characteristic of a pure public good, related to the former two, is non-measurability. The exact quantity or quality of a pure public good either cannot be measured directly or measurement entails considerable cost. It is therefore difficult to assign individual units a value or price. Pure private goods, on the other hand, are characterized by easy or no cost exclusion of non-paying consumers, exclusive or rival consumption patterns, and easy or no cost measurement of product quantities and qualities.

3.5 While the above discussion relates to extreme cases, the properties of exclusion, consumption rivalry, and measurability actually vary substantially in degree. It is seldom impossible, but rather more or less costly and difficult to enforce exclusion of 'free riders' from the benefits of a good. Few, if any, products feature complete non-rivalry in consumption due to problems of congestion (eg. on roads and bridges) which reduce the quality of the good or service. The costs and difficulty of measuring the quantity and quality of products supplied differ widely. Hence, the notions of pure public or private goods are ideal concepts with relatively few products conforming with their strict properties. For our purposes, public goods are those featuring very costly or difficult exclusion of 'free riders', the possibility of joint consumption by many parties, and very costly or difficult measurement; private goods are those featuring low cost exclusion of 'free riders', limited possibilities for joint consumption, and low cost measurement of quantities and qualities. Many products may combine public and private good properties.

3.6 The suppliers of goods which feature non-exclusivity and non-rivalry (eg. public goods) cannot recoup their full earning potential. In such situations, there will be a tendency towards under-production (or no production) of such goods if production decisions are profit motivated. The state, with its unique powers of taxation over actual and potential consumers, can potentially insure the optimal supply of such public goods. The determination of payment levels for such goods is generally relegated to the political
process rather than based on marginal benefit calculations. On the other hand, goods for which exclusionary mechanisms can be readily applied can be profitably supplied by the private sector and at socially optimal levels. Prices for such goods are negotiated between suppliers and consumers.

3.7 Another means of assessing the appropriate public/private sector mix is to consider the range of potential market and government failures which might be applicable to a particular case. Market failure occurs when externalities are present, when information conditions are highly imperfect, and/or when production involves economies of scale.

3.8 Externalities or 'spillover' effects arise when an individual or firm in the course of rendering (or consuming) some service for which payment is received (made), coincidentally also renders services or disservices to other persons/firms for which payment cannot (economically) be exacted from the benefitted parties or compensation enforced on behalf of the injured parties. Typically, the parties causing the externality will not take the positive or negative effects of their actions into consideration when making production or consumption decisions. As a result, the full social benefits and costs associated with private activities will not be reflected in market prices and either more or less than the socially optimal level of supply will be provided.8

3.9 Either as a result of wide changes in market or environmental conditions, the complexity of the product offered, wide distance separating producers from consumers, poor infrastructure, or other factors, the information available to producers or consumers may be inadequate to make rational production and trading decisions or may be asymmetrically distributed among parties. In the latter case, there may be opportunities for suppliers to misrepresent the nature or quality of their goods (eg. 'moral hazard') bringing excessive or unnecessary costs to consumers. These and other types of information imperfections lead to high levels of risk and transaction costs which, in turn, constrain specialization and exchange in markets.

Agency costs are one important set of costs associated with asymmetric information. Where

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8 Externalities can be internalized, thus incorporating the benefits or costs of the incidental services back into the decision-making process. This can be done through negotiated transactions between the suppliers and the benefitted/inflicted parties or through a merger of the different parties. Both such methods, however, may involve substantial transaction costs, particularly where the number of affected parties are many and the value or cost of the incidental services/disservices is difficult to measure. Negotiating appropriate levels of compensation may be an extended and costly process.
information is unequally distributed, the producer or financier of a product (eg. the principal) will have
difficulty detecting whether market outcomes derive from the efforts or skills of the distributor (eg. the
agent) or from some exogenous factors. The agent, whose interests do not fully coincide with those of
the principal, may perform in ways which reduce the principal's gains from exchange, yet which the
principal can detect only at high cost. As with externalities, agency costs may inhibit specialization and
exchange within markets.

3.10 Where activities are subject to economies of scale, market supply of goods may not result in
efficient outcomes. On the one hand, high fixed costs may be incurred before efficient operating scales
are reached, this inhibiting entry and exit for many parties. While it is possible for individuals/firms to
achieve economies of scale through joint efforts, the negotiation and implementation of cooperative
agreements will be costly to achieve, with the potential for 'free riders' and agency problems (Olsen
(1965). On the other hand, there may be circumstances where the lowest cost mode of production is
achieved by a monopoly (eg. a 'natural' monopoly). Unless the monopolist is able practice price
discrimination amongst (potential) consumers, it will produce a lower quantity and charge a higher price
than the social optimum. The monopolist will also have less incentive for innovations in product
development, leading to losses to society in a dynamic sense.

3.11 Under the above circumstances of externality, information imperfections, and economies of scale,
there are economic justifications for government interventions in markets. In fact, the absence of public
institutions and investments frequently perpetuates market failure. However, government intervention need
not take the form of supplanting private provision of goods through direct public sector production and
delivery. There are a range of alternative interventions, such as taxation, regulation, subsidization, and
coordination that seek to remedy specific forms of market failure, while maintaining the private sector
as the dominant supplier of goods. Some such interventions may be geared toward reducing the
transaction costs faced by private suppliers and consumers in undertaking collective action on their own.

3.12 Whether public sector assumption of a direct production role or government support or regulation
of private practices improves market performance depends upon the costs of public policy. This will
depend upon such factors as: the information available to government, the decision-making criteria and
process employed, and the efficiency of government bureaucracy and state-owned enterprises in
implementing decisions. Governments are also prone to failure, at least in economic terms.
A combination of political objectives and constraints and weak administration may lead governments to intervene in ways which are economically harmful. State-owned enterprises whose production decisions are influenced by political considerations and that are not held accountable for their financial performance operate under an incentive structure not geared to economic efficiency. Both state-owned enterprises and the general government bureaucracy may operate with widespread 'agency' problems with public officials pursuing their own agendas in addition to their official mandate. Other forms of government intervention frequently create or strengthen vested interests, which make it difficult to change economically harmful policies. Some such interventions may strongly inhibit market entry, constraining both market and private sector development.

3.13 Given that both private and public activities are subject to various forms of potential 'failure' it is important to consider the alternative means by which both private and public tasks are accomplished. What alternative institutional arrangements are available to organize private production and distribution? How might public tasks be organized? What combinations of public and private roles can be developed to benefit from or compensate for the relative advantages and disadvantages of each?

3.14 In the discussion below, we apply these theoretical issues to the organization of seed systems, distinguishing between functions which are appropriate for informal and formal seed systems and, within the latter, for the public and private sectors. A range of alternative institutional arrangements for coordinating decisions and actions within formal seed systems are also discussed.

Informal vs. Formal Seed Production and Supply Systems

3.15 An important characteristic of seed is its ability to reproduce itself. As a result, farmers do not need to obtain their seed requirements from external sources; farmers can serve as their own suppliers. Farmers can conduct their own varietal selection and testing work, undertake seed multiplication, processing, and storage, and exchange seeds as well as information related to their performance. It should be mentioned, however, that the seed retained and exchanged among farmers is frequently not of the same quality as that generated by good commercial seed sources.

3.16 For the individual farmer, seed selection and retention will involve several types of costs, yet offer several types of potential benefits. The costs will combine: 1) the normal costs of crop production, 2) the additional labor and other costs associated with the more careful husbandry practices required (eg.
more intensive weeding and removal of off types) or the longer production cycle of the seed crop, 3) the costs of seed cleaning and drying, 4) the costs of seed quality tests, 5) the costs of storage, including seed deterioration, and 6) the opportunity costs associated with reduced consumption and/or market sale of the crop in its edible or processable form. For some crops, the direct production costs (e.g. 1 through 4) incurred by farmers will be lower than the costs of commercially produced and supplied seed, although this is partly because the latter entails more intensive post-harvest treatment and grading. In addition to lower production costs, other (potential) benefits from farmer seed retention include: zero transaction costs, high reliability of seed supplies, and consistent or predictable seed performance.

3.17 In addition to the farmer's own technical know-how and experience, other important factors affecting the cost-benefit ratio for farmer seed retention are the prevailing agro-technical and environmental conditions, and the type of crop or variety. Farmers retaining their own seeds are vulnerable to total seed loss in the event of drought or other adverse natural event. Risks of farmer production and seed storage are higher under rainfed than irrigated conditions and when seed harvests are made in humid rather than dry weather. Risks will be higher for crops for which the edible/usable form of the crop is but a precursor to the seed (e.g. vegetables, fodder crops) than for crops whose seed is the mature grain (e.g. wheat, maize, rice, grain legumes) given the extended production cycle involved for the former.

Farmers risk declining productivity if the genetic and physical purity of the seed is not maintained and as varieties become susceptible to new types of diseases and insects. Varietal deterioration in farmer-retained seed is generally very low in the case of self-pollinated crops, moderate for cross-pollinated crops (because they may become genetically mixed with other varieties in nearby fields), and very high in the case of hybrids which tend to progressively lose their hybrid vigor with each multiplication. Different crops also vary in their susceptibility to disease and pests and in their storage properties. It is generally more difficult for farmers to retain seeds for crops which are vegetatively propagated (e.g. cassava, sugar cane) because of a high risk of disease development and spread.

3.18 Farmers will substitute for or supplement their own seeds by purchasing seed from others in circumstances where a superior or alternative variety is available, the previous standing crop was sold, the purity (or resistance to diseases and insects) of farmer seed stocks has deteriorated, or it is easier or less costly for the farmer to obtain seed from external sources rather than undertake production and storage him/herself. External suppliers may be in a position to produce higher quality seed or produce seed at lower cost by utilizing specialized knowledge in plant breeding or seed production, better
operating conditions (eg. irrigation), and/or better facilities for seed processing and storage. The yield or other advantages of the purchased seeds may render the benefit-cost ratio associated with such seeds to be higher than that for farmer-retained seeds, although farmers incur transaction costs and direct purchase costs when procuring seeds from external sources. For truly superior seeds, farmers may be willing to pay prices several times their own production costs and several times the market prices for the harvested crop.

3.19 One potential external source of seed supply for farmers is nearby farmers or communities. In particular areas, individual farmers or villages may specialize in seed production and storage, selling or bartering their production within a local area. Such seed production and delivery systems may provide significant advantages for farmers. In the first place, the transport and other market access costs faced by farmers will be relatively low. Such systems will provide greatest cost savings in remote regions and for crops requiring very high sowing rates (eg. wheat, beans, groundnuts). Secondly, farmers would expect that the varieties produced would be well adapted to the local agro-ecological conditions. Hence, such systems would be especially appropriate in less advantaged areas and narrow agro-ecological zones (eg. mountainous areas). Thirdly, such systems should feature relatively low transaction costs since there might be a strong degree of good will and personalization between the suppliers and users. The close proximity of suppliers and users and the social ties within local communities would be expected to reduce the degree and significance of information asymmetry.

3.20 The above arrangements of farmer-retained seed and community-level seed production and distribution jointly constitute what are regarded as 'informal seed sub-systems'. As the discussion has indicated, such arrangements may be very suitable (eg. cost effective) for some crops; highly unsuitable for others. Table 1 compares the technical features of these different crops.

3.21 A second external source of seed for farmers is formal seed production and delivery systems, involving specialized public and/or private seed producing and distributing enterprises. Formal and informal seed sub-systems may be complementary with new varieties or replacement seed being supplied by formal seed enterprises with additional distribution activities and further seed multiplication occurring at the community level. Such sub-systems may also compete with one another, especially in the supply of replacement seed. Whether or not formal seed producers and distributors can effectively compete with informal arrangements will depend upon the formers’ cost efficiency, their quality of seed, and their effectiveness in reaching farmers and promoting their products.
Table 1: Comparative Suitability of Crops for Informal Seed Sub-systems

<table>
<thead>
<tr>
<th>Breeding System (Pollination)</th>
<th>Wheat</th>
<th>Rice</th>
<th>Ground Nuts</th>
<th>Potato</th>
<th>Maize</th>
<th>Sorghum/ Millet</th>
<th>Vegetables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self</td>
<td>Self</td>
<td>Self</td>
<td>Self</td>
<td>Self</td>
<td>Open/ Cross</td>
<td>Open/ Cross</td>
<td>Varied</td>
</tr>
<tr>
<td>Rate of Genetic Deterioration</td>
<td>Slow</td>
<td>Slow</td>
<td>Very Slow</td>
<td>Slow</td>
<td>Rapid</td>
<td>Med (50)</td>
<td>Rapid (50)</td>
</tr>
<tr>
<td>Multiplication Factor</td>
<td>Low (25)</td>
<td>Med (50)</td>
<td>Low (10)</td>
<td>Low (10)</td>
<td>High (100)</td>
<td>High (100)</td>
<td>Varied</td>
</tr>
<tr>
<td>Sowing Rate/ Hectare</td>
<td>High (100)</td>
<td>High (50)</td>
<td>High (125)</td>
<td>High (2000)</td>
<td>Med (20)</td>
<td>Low (10) (10)</td>
<td>Low (&lt;10)</td>
</tr>
<tr>
<td>Availability of Improved Varieties</td>
<td>Many</td>
<td>Many</td>
<td>Few</td>
<td>Few</td>
<td>Many</td>
<td>Few</td>
<td>Many</td>
</tr>
<tr>
<td>Timing for Seed Replacement (Yrs)</td>
<td>4+ 4 Varied</td>
<td>4+ 3+ (1)*</td>
<td>3+ (1)*</td>
<td>3 (1)*</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suitability for Informal Sub-systems</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low-Med</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

* Annual seed replacement for hybrids and seed replacement every three years for composites.

Sources: Cromwell (1990); Crissman (1989)

3.22 The transport and transaction costs associated with seed procurement from formal systems would be expected to be higher than in informal sub-systems as seeds are delivered over greater distances and as the users will not have direct contact with the producers. To compensate for such (expected) higher transaction costs, formal systems may have production cost or product quality advantages stemming from higher levels of scientific input, greater management skills, and economies of scale and scope in the use of modern production, processing, and storage facilities. In general, formal seed sub-systems are expected to have greatest advantage over informal arrangements for seed crops (and varieties) requiring high levels of scientific input (e.g. hybrid varieties) or specialized techniques for effective production, processing, and storage (e.g. vegetatively propagated crops), as well as for relatively high-value crops whose seed constitutes a very minor component of total production costs (e.g. horticultural and fodder crops). In circumstances where self-pollinated varieties lose their resistance to diseases or insects or where seeds
for such varieties cannot be properly stored on-farm, formal seed supply arrangements may also be financially viable.

**Alternative Institutional Arrangements in Formal Sub-systems**

**Varietal Development (Plant Breeding)**

3.23 Varietal development work has several characteristics which generate problems of economic organization. One set of problems relates to the actual performance of plant breeding activities while another set of problems relates to the appropriation of benefits from such activities. These problems will be discussed in turn, to be followed by a discussion of alternative institutional mechanisms for countering them.

**Economic And Technical Characteristics of Plant Breeding Activities**

3.24 Varietal development work is inherently highly risky. Considerable levels of basic scientific research followed by extended and extensive varietal selections, crosses, and trials may still not result in an improved variety from a technical, let alone commercial standpoint. The process of varietal development may involve long gestation periods for scientific work, selection, and testing, with the successful development of an improved variety taking 5 to 15 years, depending upon the type of crop, the availability of germplasm, and the level of investment in scientific and other resources. The successful (and unsuccessful) development of an improved variety is a costly process, frequently entailing sunk costs of $2-3 million.

3.25 Such features of the varietal development process create barriers to entry and exit, limiting participation in this line of activity to those organizations able to achieve the necessary scientific grounding as well as bear the potentially significant financial and other risks (Kelly (1989). At the same time, varietal development work provides some opportunity for achieving economies of scale or scope, especially in terms of the (full) use of scientists, laboratories, germplasm collection facilities, seed testing facilities, and accumulated technical know-how. In small markets and in circumstances where the available scientific resources are very limited, such features may result in the monopolization or concentration of varietal development activities. In addition, the considerable riskiness of plant breeding work may lead to a bias in the direction of work toward less risky ventures in close 'vicinity' to the

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9 This paragraph is based on McMullen (1987).
existing research base and varietal mix (Stoneman (1987). Such conservative varietal development strategies may neglect highly risky plant breeding activities which are nonetheless very important for the development of the national agricultural sector.

3.26 Problems of economic organization also derive from the commercial risks associated with plant breeding. Improved seed has significant public good properties—it embodies new technological knowledge which can be used repeatedly and by many farmers simultaneously without depleting it (eg. non-rivalry) and can frequently be reproduced at little cost and used by parties who do not make payment to the breeder (eg. non-exclusivity). In addition, the genetic information embodied in improved seeds can be absorbed by competing seed enterprises and used to their competitive advantage.

3.27 These characteristics of seed-embodied genetic information create serious obstacles for profit-oriented firms to invest in plant breeding. In order to recoup and show a financial return on their investments in plant breeding, the breeder must be in a position to sell the fruits of its R&D. However, once the breeder releases its improved variety, the information embodied in the seed can potentially be acquired by many parties at little or no cost. A problem of 'appropriability' thus exists.

3.28 From a social welfare perspective there are significant positive externalities associated with effective plant breeding work. While the improved variety contributes significant value added, this may be captured largely by farmers, consumers, processors, and competing seed enterprises and not by the breeder itself. A conflict exists in that while society would prefer that the knowledge be widely available and that incremental units of this knowledge be supplied at their marginal cost, this may be inconsistent with the breeder's need to recoup its investment. The result of this is likely to be the under-investment in socially beneficial varietal development activities by profit-seeking enterprises.

3.29 The severity of this appropriability problem within the seed sector depends upon a number of technical and economic factors. Particularly important is the actual cost and difficulty of reproducing the knowledge embodied in seed. In the case of hybrids, it is frequently not possible for farmers to reproduce

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10 The costs of reproducing the knowledge are those of multiplying the seed.

11 Certainly a time lag usually exists between the release of a new variety and its multiplication or copying by competing firms. Firms may be able to appropriate economic rents from a new variety for several years before similar products are brought onto the market.
the seed, maintaining the same gene components. Saving seeds from a hybrid crop will result in lower productivity as the seed loses some of its hybrid vigor. Breeders of hybrid crop varieties thus have some natural or biological protection against the uncompensated dispersion of their value-adding technical knowledge (Kelly 1989).¹²

The 'competition' which private plant breeding firms face from farmers (and thus the scope for appropriating the benefits from improved varieties) will also be less for many vegetable and fodder crop seeds, which farmers find both costly and difficult to effectively reproduce. With the cost of purchased seeds for such crops being relatively low compared with the commercial value for such crops, it is normally uneconomic for farmers to reproduce their own seeds of these types.

The appropriability problem is most severe in the case of self-pollinated crops whose harvested grain is close in character to that of commercial seed. For several such crops, particularly wheat and rice, it is relatively easy for both farmers and competing seed enterprises to reproduce seeds without loss of quality. Varietal development work for self-pollinated crops thus has very strong public good properties.¹³

**Alternative Institutional Arrangements for Plant Breeding**

3.30 A range of different institutional or other mechanisms can be adopted to counter the technical, financial, and commercial risks noted above. Several strategies, including, forward integration, hybridization, and rent-seeking, can be undertaken by private firms themselves to enhance appropriability. Firms may be able to increase their market shares, charge prices above marginal production costs, or limit competitor duplication of their varieties by integrating forward from varietal development into seed multiplication and/or distribution activities. In doing so, the plant breeder gains better control over the use of its varieties and can differentiate its products in the eyes of farmers through the provision of

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¹² This 'natural protection' may not be complete since competing firms may be capable of dissecting and then reproducing hybrid varieties. Market structure may thus be an important factor affecting breeder appropriability of benefits.

¹³ The actual amount of money that the firm would need to appropriate in order to undertake a breeding program will vary according to the costs incurred and time taken to develop the improved variety. This will depend in part upon the overall state of technology, the availability and employment costs of breeders and other scientists, and the available germplasm base in the country. This will also depend upon the techniques required for the particular crop or variety and the need for labor, facilities, mechanical devices, etc. A third set of factors are firm-specific and will relate to its existing store of technical knowledge, its management, and its R&D and product strategy. More diversified firms may be more willing to undertake research where appropriability is a problem as this would be part of its wider product development and marketing strategy.
additional services (e.g. technical information, credit). Such forward integration, however, may be very costly, requiring acquisition of new skills, investments in new facilities, etc.

Enhanced appropriability may be achieved by focusing on developing hybrid seeds of crops normally produced through self- or open-pollinated means (e.g. rice, wheat, and maize). Farmers are frequently willing to pay considerably higher prices for well-performing hybrid varieties. Part of the higher margins from hybrid seed production and distribution can be used to defray fixed investment costs in varietal development. Plant breeders can also enhance their appropriability by lobbying their governments to provide barriers against competing firms operating in the local market. The social costs of the latter will normally exceed the private lobbying costs to the firm.

3.31 Three other institutional mechanisms—the adoption of plant breeders' rights, the public subsidization of private plant breeding activities, and the direct public provision of plant breeding—all entail some form of collective action. Plant breeders' rights (PBR) and similar laws are designed to enable breeders to control against the unauthorized use of their varieties by competing firms and to reap benefits, in the form of royalty or licensing payments, from the authorized use of their varieties, germplasm, or techniques by other firms. PBRs serve to 'internalize' part of the external benefits from varietal development and release. However, PBRs tend to offer only limited protection.14

3.32 A second mechanism to counter the high risks of varietal development work and the appropriability problem is for the public sector to subsidize private investments. This can be done in various ways including direct grants, training of plant breeders, low-cost leasing or supply of facilities, secondment of personnel, low or no cost provision of germplasm or inbred lines, etc. Unlike PBR, this mechanism can also be used as a means of promoting competition in the seed sector by reducing the costs of entry. A related mechanism is for the government to contract private firms to undertake the breeding of particular types of varieties with the commercial rights and risks being maintained by the contracting organization.

It may be the case that the government organization is less risk averse or better able to bear risk than a private firm and so it would be beneficial for the public sector to bear some of the burden of private risk. The government can also contract out a series of R&D programs with differential risks and

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14 In the first place, the PBR legislation in most countries specifically permits individual farmers to multiply seed for their own use. This would be quite common for open-pollinated crops. Secondly, given the extreme variability in seed quality, it may be very difficult to detect small infractions of PBR laws and very difficult and costly to enforce one's rights through the legal system.
so have a diversified portfolio of programs which it is underwriting. However, the implementation of such arrangements may entail considerable 'agency' costs and, in the face of corruption and favoritism, the allocation of public resources to individual private firms may have anti-competitive effects.\(^{15}\)

3.33 A third mode of collective action is the direct performance of varietal development functions by public sector organizations such as governmental research stations, parastatal enterprises, or universities. This arrangement overcomes the appropriability problem since the public organization normally does not have to earn a financial profit from its investment in breeding as long as the social benefits of its work are deemed significant. The ability to draw upon government budgets and subsidies relieves the public plant breeding organization from having to capture much of these social benefits. Public sector plant breeding can also be pro-competitive as long as the breeder seed for the improved varieties is dispersed among different production and distribution channels. Public sector plant breeding may counter the bias against risky R&D ventures since the government can diversify across a range of R&D projects.\(^{16}\)

Several problems may be associated with public sector varietal development operations, these being generally associated with the nature of incentives within public organizations. Rather than being less risk averse than private firms, public breeding organizations and researchers may be particularly conservative, seeking to avoid any major mistakes. Innovation is frequently not rewarded in bureaucratic structures. Public sector seed breeding may also be relatively high cost since managers and researchers have little incentive to hold down operating costs and may in fact seek to expand their budgets. With their financial resources coming more from government sources rather than from the sale of their goods/services, such organizations are expected to be responsive to conveniences and political considerations and pressures as well as to the preferences and communications of farmers and consumers.

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\(^{15}\) The public support organization must monitor the patterns of use and effectiveness of the resources provided. As some resources may be fungible, it is likely that the private firm will direct the publicly provided resources into R&D areas where the firm would have invested on its own account (e.g. for hybrid seed development) and neglect lines of R&D which are not profitable, but required for the overall development of the agricultural sector. With contracting-out, there is the risk that the firms will withhold all or part of their results for their own use at a latter time. Contracting-out of research may also involve problems in appropriately pricing the outputs of such research.

\(^{16}\) Even where plant breeding research is undertaken by public institutions, the 'private sector' may still participate in the form of field tests of new varieties in farmer fields. Such arrangements not only assist in selecting the most appropriate varieties for release, but also help facilitate the later acceptance of the varieties by farmers.
Seed Imports

3.34 It may take a new seed industry several years to develop the production capacity to meet domestic seed demand. For many crops the importation of seed is feasible and can build up local supplies much faster. In addition, imported seed may be more cost effective even over the longer term for minor crops or crops whose seed is difficult to produce under local agro-ecological conditions. For small countries, it may be economic and expedient to import many types of seed rather than seek to develop local plant breeding and seed production facilities. Where imported seed performs well under local conditions, its purchase and distribution can be a profitable activity.

3.35 The potential problems associated with seed imports relate to 'moral hazard' and negative externalities, although certain institutional arrangements can often minimize their importance. Plant varieties are typically developed for a particular agro-ecological zone and frequently do not perform well when used in a different agro-ecological region. Local adaptation tests within the target agro-ecological region are essential before commercial imports are made of a particular variety or hybrid. An additional barrier to long-distance trade is that seed, as living organisms, is subject to deterioration in quality in the course of storage, handling and transport. The importer generally encounters a situation of asymmetric information in which the exporter, who holds the seed or who has seen it and knows its 'history', is better informed about the quality and performance potential of the seed than is the importer. At least in the short run, an exporter might benefit from misrepresenting the quality of the seed.

3.36 A potentially more serious problem is that seed importation may also introduce exotic pests, diseases, and noxious weeds whose behavior in the new environment is unpredictable. This may result not only in low productivity for the new crop to be planted, but also adversely affect the existing crop as well as other crops or livestock grown locally. Negative externalities associated with the distribution and use of the imported seed could thus be significant.

3.37 There is thus a need for an institutionalized system of seed inspection, testing, and (where necessary) quarantine. Economies of scale (or scope) will be associated with such a service as there will be scientific and financial benefits in combining seed import inspection, testing, and quarantine with the inspection and certification of seeds and other plant materials for export so to meet the phytosanitary and other standards of other countries. Both because of the 'moral hazard' problem mentioned above and the potentially anti-competitive effects of having one or a few private seed companies undertaking seed inspection services for the nation, such services are an appropriate task for the public sector.
Seed Multiplication

3.38 The multiplication of seeds can be regarded as a two-stage process with breeder seed first being multiplied to produce a larger supply of genetically pure foundation seed and then this seed being multiplied to produce commercial seed. In the case of hybrids, inbred lines are the equivalent of foundation seed.

3.39 Compared with plant breeding and seed inspection work, there are significantly less externalities involved in seed multiplication. The exception to this lies at the stage of foundation seed production. Foundation seed will subsequently be used over a wide area to produce commercial seed. The loss of genetic or physical purity in foundation seed will have adverse multiplier effects on the subsequent production of commercial seed and on seed marketing efforts.

3.40 The appropriation of benefits from seed multiplication is difficult in the case of self-pollinated crops since the multiplication of such seed is technically easy and can be done at relatively low cost. Not only must commercial producers compete with farmers in the supply of such seed, but they also face the prospects of competing firms further reproducing and distributing the same seed in the same markets. For crops in which the seed is also the edible food (e.g. rice, wheat, potatoes), the price which can be charged for commercial seed can only exceed that of the crop by a narrow margin, limiting the profit potential from seed multiplication activities. Such problems of appropriability are less severe for open-pollinated and (especially) hybridized cross-pollinated crops since some degree of biological protection is provided to the seed multiplier.

3.41 A 'moral hazard' problem exists in seed multiplication which may reduce the efficiency of commercial supply. This is due to the facts that: 1) many of the important quality attributes of seed are not directly observable and 2) many factors, including environmental conditions, labor effort, management skill, and the properties of the initial breeder or foundation seed, contribute to the quality of multiplied seed. It is not only difficult and costly to detect or measure the quality of seed, but it is difficult to assess the relative importance of different factors in the end product. Unless institutional arrangements are developed to counter such information gaps, there may be incentives for seed producers to seek to sell their seed with a higher quality grade than is warranted by actual results.

3.42 Although not as significant as in the case of plant breeding or seed inspection work, there are some economies of scale in seed multiplication. This varies considerably among crops, depending upon the
scope for mechanization of planting, harvesting or other functions and the intensity of crop husbandry required. While for many field crops, scale economies can be reached for seed multiplication over dozens or even hundreds of hectares, for horticultural crops and for most hybrids, heavy labor and management requirements present diseconomies of scale beyond a few hectares.

3.43 These features of seed multiplication have a bearing on the appropriate roles for the public and private sectors. The externalities associated with foundation seed multiplication require close supervision in production and very strict standards for approval and dissemination. Where private firms have developed the varieties (and breeder seeds) we would expect them to seek to protect their investment by directly undertaking foundation seed production. Where the varieties are developed by public institutions, foundation seed production is expected to be undertaken by public seed companies or by selected contract growers, operating under close supervision.

The significant appropriability problem associated with multiplying commercial seeds of self-pollinated varieties is expected to severely limit the participation of for-profit enterprises which must bear major overhead costs, particularly those associated with R&D activities. This function will yield insufficient profit margins for such firms. In contrast, the multiplication of seeds for self-pollinated varieties may be economically viable for small-to-medium-scale firms who have low cost access to public or private varieties. The 'moral hazard' problem can be dealt with by seed enterprise supervision of the production process and through the establishment and enforcement of seed quality standards (see below). The potential economies of scale in seed multiplication are not of a magnitude which would be expected to result in monopolies or other high levels of concentration in production which might require government regulation.

3.44 There are three other types of circumstances in which public sector interventions in seed multiplication may be justified. The first of these is in the very early stage of seed system development when the private sector is not well organized. At such a stage, public sector agencies may have to directly undertake seed multiplication or assume major administrative, financial, and risk-bearing roles in the nascent private sector. A direct involvement by public sector organizations may have a demonstration effect, stimulating private investments in what can be regarded as an 'infant' industry.

Public sector intervention can be justified on equity grounds in the case of seed multiplication for minor crops or for varieties appropriate for very specific agro-ecological zones. Such activities may not be profitable for the private sector. The same holds true for the multiplication of particular seeds for
retention as emergency stocks. In both cases, public sector financing, subsidization, and/or direct participation can be justified.

Seed Processing

3.45 Seed processing is frequently the component of the production-distribution process which requires the largest capital investment. This is because some separation, drying, cleaning, grading, chemical treatment, and packaging activities either require or are more efficiently performed with mechanized equipment. This does not mean that large-scale processing facilities are required, only that some minimum scale should be attained for maximum efficiency. Many seed crops can be processed with the same equipment, although this requires adjustments in the machine calibrations. The technical difficulty of seed processing varies among crops, being relatively easy for most field crops and considerably more difficult for most vegetable, oilseed, and forage crops.

3.46 In considering the alternative organizational arrangements for seed processing, one is concerned less with issues of public vs. private sector participation than with issues regarding the appropriate degrees of decentralization and specialization of processing activities. There is little economic justification for public sector involvement except where the technical skills and investment requirements for processing a particular seed crop are not yet readily available in the private sector or where economies can be gained by integrating processing activities with existing public sector seed multiplication operations. Generally, seed processing can be a value-adding activity for private seed producers or traders or a profitable activity for private enterprises specializing in this activity. While it may be the case that official quality control measures can be effectively undertaken only at seed processing sites, this does not mean that a public sector organization must itself perform the processing activities.

3.47 With regard to the location of seed processing facilities (eg. centralization vs. decentralization), an important issue is transportation costs and the effectiveness of transportation systems linking seed producers, processors, downstream distributors, and the users. Seed processing facilities will be required in major seed producing areas. In some cases, it may be possible to bring processing facilities to farmers via mobile processing units. The appropriate degree of specialization in seed processing will depend upon a range of factors including the technical skill and machinery requirements for individual seed crops and the volume and seasonality of deliveries.
**Seed Quality Control**

3.48 Two features associated with the quality of seeds generate problems for economic organization. The first of these features is that the quality of seed is defined according to a multiple set of criteria, with attributes associated with their genetic make-up, their physical condition, their agronomic characteristics, and the characteristics of the resultant crop. Characteristics frequently valued by farmers and others include: genetic yield potential, seed vigor, varietal and physical purity, disease-resistance, length of time to maturity, germinability, and the physical appearance and nutritional and cooking qualities of the harvested crop. These and other quality dimensions may be valued differently by (different types of) farmers, consumers, processors, breeders, and others with a stake in the seed system. The multidimensionality of seed quality presents problems for determining and communicating the quality attributes of particular varieties or particular consignments of seed.

3.49 The second important feature was mentioned earlier—the non-observability of many quality characteristics and the difficulty (and time delay) in their actual measurement. Due to asymmetric information, there are opportunities, at least in the short run, for producers or distributors to benefit from misrepresenting seed quality. That this possibility exists may lead (potential) buyers to discount the actual value of the seed, reducing their purchases or the price they are willing to pay (Akerlof (1970). There are potential externalities involved here. The actual distribution of low quality seed may have the knock-on effect of reducing farmer confidence in other commercial seeds. Alternatively, the sale of high-quality seed may induce farmers to not only purchase larger quantities of the same variety in the future, but to also make larger purchases of other types of commercial seed.

3.50 Despite the 'moral hazard' problem and the potential externalities associated with seed quality, there is scope for a considerable role for the private sector in quality control. Most quality control activities do in fact take place within the seed producing firms themselves—on their own farms, in their supervision of contract growers, and in their processing activities. In a competitive market, firms will obtain, maintain, and expand farmer patronage by supplying only high-quality seed and gaining a reputation for doing so. As a means of signalling the quality of their products and establishing accountability for them, private firms attach brand names to their products and promote them (Klein and Leffler (1981). Private firms can offer money-back guarantees on their seeds. Such market mechanisms for quality assurance may not be operative, however, when a monopoly exists or where the available market information is so limited that farmers are unable to associate products (and thus responsibility for quality) with particular suppliers.
3.51 Quality control may also be undertaken by the private sector through collective action. Seed producer or trade associations can establish guidelines for seed testing, a system of seed quality standards, and even joint facilities for crop certification and seed testing. Such self-policing activities may enhance private sector profitability by filtering out low quality producers from the market and by enhancing the overall image or reputation of the industry for quality.

3.52 Governments may intervene in the seed market in order to protect and promote the public interest in the realm of quality control. Such interventions can take various forms, including:

   a) government regulations specifying that seed producers perform certain tests and report the results of these tests through labels on packaging. In this case, the government will need to enforce truthful labelling and perhaps assist private producers (e.g. through training) in developing the capacity to perform necessary tests.

   b) government-set seed quality standards which must be met for seeds to be commercially distributed. Seed standard provisions will provide a common language for communicating seed quality, and enable comparisons among varieties. The challenge here is to set the standards at appropriate levels. Standards set at too high a level will result in barriers to entry and exit and provide incentives to cheat. Standards set at too low a level will allow mixed or low quality seed to pass through the system with official sanction.

   c) government seed inspection and testing services with crop and seed certification and provision of government labels. Such systems are designed to prevent the distribution of low quality seeds and to prevent seed enterprises from marketing non-superior varieties simply to recover their sunk costs in varietal development and/or seed multiplication. A potential problem lies in the possible alignment or collusion between producers and the regulatory agencies, undermining the credibility of certification (Stigler 1971) The risk of this is probably highest when the producing enterprises are government agencies and there is political pressure to approve the seed.

   d) spot checks by government inspectors in the market place.

   **Seed Storage**

3.53 Due to the perishability of seeds as living organisms and the seasonality of both seed production and use, seed storage is a very important function. Inadequate seed storage results in loss of seed quality (e.g. in their viability and rates of germination), in problems of making supplies available on a timely basis, and increased operating costs for seed enterprises.

3.54 The incentives to undertake seed storage and the technical and economic barriers to doing so effectively differ according to the form of storage and the type of crop. For example, private sector seed
processors and traders are expected to maintain seasonal carry-over and in-season distribution stocks as an integral component of their marketing strategies. The barriers they would face would be largely technical, requiring them to develop the necessary knowledge and facilities for proper seed storage. One would expect that the organization of such forms of storage will simply reflect organizational patterns further upstream and downstream.\(^7\)

3.55 In contrast, there would be considerably less incentive for private firms to maintain significant reserve stocks of food crop seeds to compensate for a drought or other natural event which greatly diminishes the availability of seed. Only in a relatively mature seed system would we expect firms to maintain multi-year seed stocks in order to maintain their market shares during the season of seed shortage. For crops whose seed is normally retained by farmers there would be little opportunity for profit in long-term seed storage. The holding of reserve seed stocks is thus expected to be a function undertaken by the public sector or else contracted out to a private firm by a public organization.

3.56 Regarding varietal maintenance, individual breeders have the incentive to maintain pure lines of their own varieties. However, private firms may decide to drop certain types of research and in the process discard the relevant germplasm. Both to preserve biological diversity and to preserve continued access by both public and private plant breeders to a wide range of germplasm, it is appropriate for the public sector to operate or finance a varietal maintenance/gene bank unit or network. Economies of scale can be realized in the infrastructure for such operations.

Seed Marketing

3.57 Seed marketing represents the major point of contact between the producers and users of seed. Seed marketing entails several inter-related components and functions, including market research, promotion of demand, seed distribution (logistics and sales) and seed pricing. Each is associated with a different set of incentive and control problems.

3.58 Market research involves gathering, processing, and analyzing information. In the case of seed, the relevant information would pertain to: planted areas and cropping patterns, agro-ecological conditions, seed replacement rates, the proportion of plantings under improved and hybrid varieties, farmer incomes

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\(^7\) For example, where seed is to be distributed by an agricultural parastatal or project, we would expect seed storage to be undertaken by the focal organization; where seed is privately produced and distributed, it will be stored by private enterprises.
and seed quality preferences, and consumer and processor preferences. While private seed producers and traders certainly have a strong incentive to gather and process such information, government intervention in the market research process can be justified on economic grounds. Some economies of scale and scope can be realized in market research. This condition might be expected to lead to competitive disadvantages for small-scale enterprises and hence the possible concentration of the industry. The government itself, through its existing set of agricultural and service institutions, might be well positioned to collect the requisite information. The wide dissemination of such information through official publications and media would thus be pro-competitive and would be expected to increase the efficiency of seed distribution.

3.59 **Seed promotion** is done to enhance demand for particular varieties. It may involve such techniques as field demonstrations and use of television, radio, or printed media to describe the benefits of new varieties. Private seed producers and traders are expected to have a strong incentive to promote their own varieties. Nevertheless, there may also be a justification for at least a supplemental public sector role in seed promotion. Widespread farmer up-take of improved commercial seeds may generate social benefits of greater magnitude than the private benefits obtained by individual farmers and the added profits obtained by seed producers and traders. The wide dispersion of an improved variety may not only increase farmer yields, but may have multiplier effects on local services and agro-industries. Such added benefits will not be considered when a private enterprise considers its potential returns from promotional activities. Less than socially optimal levels of investment in seed promotion may thus be expected if left entirely to the private sector.

In addition, each private seed promoter will extend the message that its particular varieties are better performing than those of its competitors. Important roles for the government might be to develop and enforce truth in advertising codes or to carry out and publicize the results of comparative varietal performance tests. The danger of such government interventions is that official extension and other services may provide information/recommendations only on publicly-developed and produced varieties.

3.60 **Seed distribution** is a multi-faceted process involving both the physical movement and handling of seeds and the actual exchange of seeds, money, and property rights between and among producers, traders, and farmers. The required logistical activities (eg. transport) can be profitably performed by private firms, provided that a road system is in place and that transporters can achieve safe passage. The potential economies of scale in seed transport and handling are relatively minor. The buying and selling of seeds is also an area of potential profit for private firms and individual retailers, subject to the
existence and (usually governmental) enforcement of standard weights and measures and protection against fraud and non-payment.

3.61 Nevertheless, there may be some segments of the farming population which the private sector does not find profitable to service. For example, private firms may find it uneconomical to service poor smallholder farmers operating in relatively remote and sparsely populated areas. For equity reasons or in pursuit of objectives related to land settlement, security, etc., governments may directly undertake, promote, or subsidize seed distribution in such areas. However, such targeted seed distribution programs may result in social costs which are higher than the direct costs of the programs. Once a public seed distribution agency is created, it may seek to subsidize its trading losses from the target program by engaging in seed distribution activities in more central locations, thus duplicating and competing with the activities of private firms.

3.62 Actual seed distribution can be handled through a wide variety of delivery agents and using varied coordinating mechanisms. Possible seed delivery agents include: agricultural parastatals, agricultural project units, agricultural banks and credit schemes, cooperatives, agricultural processing firms, merchants, local farmer associations, NGO’s/PVO’s, and individual farmers. Seed distribution can be undertaken directly by seed producing enterprises through their own sales outlets, can involve cooperatives, retail dealers, or individuals as commission sales agents, can be undertaken through officially-sponsored agricultural projects, or be undertaken by processors providing a package of inputs to farmers contracted to grow raw materials for processing.

3.63 Seed pricing is another component of marketing. Private firms will seek to price their seeds so to maximize their short- or long-term profits, taking into consideration their market share, their targeted market segment(s), the pricing behavior of competitors, etc. Within the public sector, a different orientation is usually brought to seed pricing matters. For basic food crops, the prices of improved seeds are often controlled or subsidized by the government in order to counter the effects of low producer prices for food crops or to stimulate increased purchases and use of the seeds. In many cases, governments have controlled the build-up of costs and prices through the seed distribution chain and have met the gaps between production and retail prices by providing subsidies.
3.64 Numerous problems are typically associated with such price controls and subsidies. Firstly, price controls frequently render trading margins inadequate for commercial firms to participate. Second, since seed demand frequently exceeds commercial sector seed supply in many developing countries, the result is often the rationing of subsidized seed to better off farmers with the poor not gaining access. Third, price controls frequently result in large losses for public enterprises or, if set to match public enterprise costs, serve to set a price floor for the remainder of the industry. Fourth, subsidizing the retail prices of improved seed is usually unnecessary since the economic return on high-quality seed is normally very high and farmers will be willing to pay higher prices for a proven product.

3.65 Table 2 summarizes many of the major economic characteristics of seed development, multiplication, and distribution activities discussed above and indicates the strength of incentives for private sector participation in such activities. The table indicates that while the incentives for private sector participation are strong for many activities, for some very important activities (eg. varietal development and seed multiplication for self-pollinated crops) such incentives are weak or the existence of externalities, 'moral hazard' problems, and/or economies of scale may warrant government regulation, taxation, or subsidization.
Table 2: The Economic Characteristics of Seed-Related Activities and the Suitability for Private and Public Sector Participation

<table>
<thead>
<tr>
<th>Activity</th>
<th>Externality</th>
<th>Moral Hazard</th>
<th>Scale Econ.</th>
<th>Scope for Appropriability</th>
<th>Private Sector Incentives</th>
<th>Justification for Public Sector Direct Part.</th>
<th>Other Interventions*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varietal Development</td>
<td>X</td>
<td>X</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Self-pollinated Crops</td>
<td>X</td>
<td>X</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Hybrid Varieties</td>
<td>X</td>
<td>X</td>
<td>High</td>
<td>High</td>
<td>Var.**</td>
<td>Var.**</td>
<td>Var.**</td>
</tr>
<tr>
<td>Specialty Crops</td>
<td>X</td>
<td>X</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Med.</td>
<td></td>
</tr>
<tr>
<td>Varietal Maintenance</td>
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<td>X</td>
<td>Med.</td>
<td>Med.</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Seed Import</td>
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<td>X</td>
<td>Med.</td>
<td>High</td>
<td>Low</td>
<td>Med.</td>
<td></td>
</tr>
<tr>
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<td>X</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
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<tr>
<td>Seed Production</td>
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<td>X</td>
<td>Low</td>
<td>Med.</td>
<td>Var.***</td>
<td>Med.</td>
<td></td>
</tr>
<tr>
<td>Hybrid Varieties</td>
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<td>X</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Med.</td>
<td></td>
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<tr>
<td>Specialty Crops</td>
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<td>X</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Med.</td>
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</tr>
<tr>
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<td>X</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Qual. Control/Certific.</td>
<td>X</td>
<td>X</td>
<td>Low</td>
<td>Med.</td>
<td>High</td>
<td>Med</td>
<td></td>
</tr>
<tr>
<td>Seed Storage</td>
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<td>X</td>
<td>Var.</td>
<td>Var.</td>
<td>Var.</td>
<td>Var.</td>
<td></td>
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<tr>
<td>Market Research</td>
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<td>High</td>
<td>Med</td>
<td>Low</td>
<td></td>
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<tr>
<td>Seed Promotion</td>
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<td>X</td>
<td>Med.</td>
<td>High</td>
<td>Med</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Seed Distribution</td>
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<td>X</td>
<td>Med.</td>
<td>High</td>
<td>Low</td>
<td>Med</td>
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</tr>
</tbody>
</table>

* Such as the establishment and/or enforcement of standards and other regulations and the provision of subsidies (especially during the early stages of seed system development).

** This depends on the level of scientific and seed industry development in the country. At early stages, public research institutions may need to take a lead role in conducting basic research and developing inbred lines for hybrids.

*** High justification for public sector production or contracting out for foundation seed. Low justification for public sector commercial seed production (or contracting out) except in the very early stages of seed system development when private investment may be very slow to develop.
IV. Public and Private Sector Roles in Seed Industries: An International Perspective

4.1 As estimated by the American seed consulting firm, Teweles, the value of all agricultural seeds used worldwide in the mid-1980's was $50 billion. Of this total, only $15 billion (or 30%) is estimated to be the value of seeds sold commercially by private firms and cooperatives (Cultivar (1991)). Another $17 billion (e.g. 34%) is estimated to be the value of seed sold by public sector enterprises and institutes. The remaining $18 billion (e.g. 35%) is the estimated value of farmer-saved (or local community supplied) seed used worldwide. Taking the first and third groups together as constituting the 'private sector', it is then estimated that two-thirds of all seed used worldwide is supplied by the private sector.

4.2 While more land is farmed in developing countries for practically all food and industrial crops (major exceptions being wheat and soybeans), it is the industrialized countries which account for the dominant share of seeds sold commercially. It is estimated that the value of seed sold commercially in developing countries was $3.8 billion in 1988, representing only 10-12% of global commercial sales at that time (Pray and Ramaswami (1991).

4.3 Several factors account for the relatively small commercial market share of developing countries, including 1) the very high proportion of planted seed in developing countries which is farmer-saved, 2) the more limited spread of improved varieties of foodgrains in developing country agriculture, and 3) the limited development of the higher value segments of the seed industry in

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18 Determining the value of agricultural seeds and other planting materials used worldwide is very difficult given insufficient data concerning the planted areas of different crops, the seed planting rates used, and the purchases of commercial seeds in many developing countries.

19 Delouche (1982) estimates that 80% of the seed used in developing countries is farmer-saved. For self-pollinated crops (e.g. rice, wheat) and for crops grown primarily for subsistence (e.g. dry beans, millet, cassava), the proportion of farmer-saved seeds is generally even higher in most developing countries.

20 In the early-to-mid-1980's, only about one-half of the areas planted with maize, rice, and wheat in developing countries was planted with improved varieties; in contrast, the planting of improved varieties for major foodgrains is virtually universal in industrialized countries (Dalrymple (1986a, 1986b); Timothy et al. (1988).
developing countries, including those comprising hybrid varieties of foodgrain and industrial crops and improved varieties of horticultural and forage crops.

4.4 The mix between the public and private sectors in the conduct of formal variety development, seed production, and distribution activities differs among countries and for different crops within individual countries. A major constraint in the study of institutional patterns within the seed industries of industrialized and developing countries is the lack of up-to-date quantitative and qualitative information. The only exception to this is for maize for which a data base on seed industries has been developed by CIMMYT. To compensate for these data limitations a survey was conducted on the extent of participation by private enterprises, public organizations (eg. institutes, state enterprises, universities), cooperatives, joint venture firms, or other organizations in the seed sectors of some fifty-four (54) industrialized and developing countries. Information was obtained on the participation and relative importance of such organizations for seven (types of) crops, representing a range of self-pollinated crops, hybridized crops, and specialty crops and for a range of varietal development, seed production, and seed marketing functions. The crops included in the survey were wheat, rice, hybrid maize, potato, vegetables, seedlings (for fruit trees and forestry), and forage crops.

4.5 Information was compiled through personal interviews and correspondence with World Bank seed and agricultural specialists, seed specialists within the CGIAR system and academic community, and seed industry representatives, supplemented by information from recent published literature. Respondents were asked to indicate whether a particular function (eg. varietal development work for hybrid maize) is currently undertaken:

1) predominantly (eg. 90% or more) by public or government enterprises,
2) predominantly (eg. 90% or more) by private enterprises,
3) by a joint venture company,
4) by a mix of private and public organizations with no dominant role for either,
5) by private firms or farmers under contract with the government, or
6) by a seed or producer cooperative.

The respondents were asked to consider only the institutional arrangements found in the formal seed industries of the particular countries, even though for some crops farmer-saved seed or informal, localized seed production and trading arrangements could well be dominant.
4.6 To render manageable the presentation of survey findings, the institutional mix of seed sectors is provided here for a sub-sample of twenty-five countries which represent both industrialized and developing countries, different regions of the world, and countries whose seed industries are at varied stages of development. For each of these twenty-five countries the information obtained from seed/agricultural experts was supplemented or re-enforced by information obtained from recent published and other documentary sources, including World Bank project documents, CGIAR studies, country and regional studies by the Seed Technology Laboratory (Mississippi State), seed trade studies, and other consultancy and academic studies. Due to the inadequate availability of information in the case of fruit tree and forestry seedlings, the similarities in institutional patterns found between seed activities for potatoes and for other self-pollinated crops, and the similarities in patterns found for vegetable and forage crops, neither seedling, seed potato, nor forage crop seed industries will be examined here.

4.7 The analysis thus covers four (types of) crops for which there are different economic incentives for the private sector to participate, at least with regard to varietal development and seed production activities. These (types of) crops are:

1) **wheat** -- representing self-pollinated crops for which we except only limited participation by for-profit enterprises in either varietal development or seed production.

2) **rice** (in major Asian producing countries)-- also representing self-pollinated crops, but whose production (for seed) has less significant economies of scale, whose domestic markets are very large, and which has been subject to successful hybrid seed production in parts of China. Opportunities for profitable involvement by private firms at least in seed production are thus expected to be somewhat greater than in the case of wheat.

3) **hybrid maize** -- representing hybrid crops for which the incentives for private sector participation are very strong. Drawing upon CIMMYT data, the relative importance of the public and private sectors in the sale of improved open-pollinated varieties (OPVs) of maize is also examined. The incentives for private sector participation may be higher in the case of OPV maize than for either wheat or rice given the likelihood of loss of genetic purity in farmer-saved seed for the former.

4) **vegetables** -- representing specialized high value/low volume crops which are difficult for farmers to select and save, which frequently call for special characteristics to meet consumer or user demand, and which generally provide attractive margins to seed producers and traders. Private sector participation is expected to be significant.
Wheat Seed Industries

4.8 The private-public sector mix and other institutional features for wheat seed development, production, and distribution are summarized in Table 3. Large scale imports of wheat seeds take place in relatively few of the countries included in our survey. This is due to the non-compatibility of most wheat varieties outside of the agro-ecological zone for which they are developed. Where imports do occur in developing countries, they tend to involve the transfer of seeds from CIMMYT, ICARDA, and other national or regional institutions to government research institutes or to universities. Varietal development work for wheat is dominated by the public sector in nearly all developing countries, this being expected given the poor scope for appropriating the benefits from developing improved (self-pollinated) varieties. The only exceptions to this pattern are in Argentina, Chile (not shown), and several industrialized economies where the private sector has undertaken varietal development work geared toward the hybridization of wheat and the generation of varieties suitable for very specific agro-ecological areas.

4.9 Among developing countries, foundation seed production is also dominated by the public sector with production taking place on state farms and/or at universities. In only a minority of developing countries is some of this foundation seed production contracted out to farmers or undertaken by profit-seeking private firms. In sharp contrast, foundation seed production is undertaken on a strictly commercial basis in the sampled developed market economies. In the United States, there are specialized foundation seed producers while in Japan, cooperatives are given exclusive rights to multiply the breeder seed provided by public research institutions.

4.10 Among the sampled countries, the production of commercial or certified seed is conducted through a wide range of institutional arrangements. In most developing countries, it is common that large farmers are contracted by government seed organizations to multiply seed and then to sell it back to them at a premium above the prevailing grain price. Such an arrangement places the commercial risk upon government, yet relieves government agencies from having to manage large seed farms where there is a risk of total or substantial seed crop failure. The performance of such

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21 On private sector attempts at wheat hybridization, see Knudson (1990). Private sector research on wheat in the U.K. is undertaken by CBI International, a breeding institute taken over by Unilever from the government in 1987.
contracting schemes varies, although in some countries contracted farmers retain a sizeable proportion of the seed for their own use or consumption as grain. Only in a small minority of countries (e.g. Egypt, Ethiopia, Nigeria, Turkey, Colombia) does state farm production account for a large proportion of certified wheat seed. These are generally loss-making operations.

4.11 Commercial wheat seed production in advanced market economies and in some large developing countries (e.g. India, Mexico) is also undertaken by cooperatives and private firms, usually on a state or localized basis to meet the needs of farmers in particular agro-ecological zones and often in conjunction with other services provided to farmers (e.g. market information; grain processing). Such firms normally multiply and then distribute public varieties. With limited few exceptions (e.g. in Argentina, United States, and U.K.), large-scale international companies have not played a major role in wheat seed production (or distribution) given the relatively low profit margins involved and the absence of a competitive advantage for such firms in this market.22

4.12 The institutional patterns for wheat seed processing are highly varied. In developed market economies, this activity is carried out by private or cooperative seed enterprises or specialized seed processors; in developing countries, processing is either undertaken by public sector seed enterprises or some mix of private and public enterprises. Among our sub-sample of developing countries, the private or cooperative sector has a dominant role only in three countries—Argentina, Zimbabwe, and Kenya.23 Throughout the Near East and most countries of Africa, public seed corporations dominate wheat seed processing. The absence or realistic seed demand forecasting and an overestimation of economies of scale in processing has resulted in major under-utilization of public sector processing facilities and high overhead costs.

4.13 A similar contrast between industrialized and developing countries is also found for wheat seed wholesaling and promotion, although among developing countries there are somewhat fewer

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22 Annual reports from Pioneer Hi-bred Int’l, the world’s largest seed company, indicate that the firm has incurred steady losses on its wheat seed development and production activities in the United States.

23 Each of these countries feature a predominant role for large-scale commercial farmers in wheat production. Not only have such farmers provided a reliable and predictable outlet for high-quality seed supplies, but some such farmers, either individually or through farmer associations/cooperatives, have also invested in wheat seed production and processing ventures.
government-dominated systems. Many governments have used official extension services to promote the adoption of improved wheat varieties, although once the varieties have initially spread, subsequent supplies of seed have typically been generated by farmers or within informal seed networks, greatly reducing the volume of seed required from public seed corporations.\footnote{An illustration of this process in the case of Pakistan is provided by Heisey and Brennan (1989).}

4.14 Considerably greater private (and cooperative) sector involvement occurs for retail sales of wheat seed. The predominance of the private sector at the retail stage, even in countries with centralized public seed enterprises, can be attributed to the need to distribute seeds among widely dispersed farmers and the high transaction costs for farmers in acquiring seed from centralized official depots. Private producer/traders can compete with subsidized public sector delivery systems by providing higher quality seed on a more timely basis and by operating with low overhead costs. In only a few of the sub-sampled countries do government agencies play a major role in this activity. Where this occurs, seeds are distributed via credit banks or agricultural development projects (eg. Mexico, Egypt, Ethiopia, and Nigeria), sometimes with credit being linked to the procurement of public sector seed. This latter policy adversely affects market demand for seed distributed by the private sector.

4.15 For one-half of the twenty-two countries for which data are presented, the retail price of wheat seed is either subsidized, regulated, or dictated by government, often as a means of countering the low controlled prices offered by state grain marketing agencies for the harvested crop. Public seed distribution frequently constitutes a subsidy program for farmers. Price controls are especially common in Africa and the Near East. In all of sub-Saharan Africa, there are few (if any) countries for which the retail price of wheat seed is totally market-determined. In contrast, market-determined prices prevail in most of the Latin American and developed market economy countries included in our sample.
<table>
<thead>
<tr>
<th>Country</th>
<th>Variety Source/Development</th>
<th>Variety Development</th>
<th>Seed Production/Processing</th>
<th>Seed Marketing/Distribution</th>
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<tr>
<td></td>
<td>Direct seed import</td>
<td>Foundation seed</td>
<td>Commercial seed</td>
<td>Wholesalers/</td>
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<td></td>
<td>Processors</td>
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<td>DEVELOPED ECONOMIES</td>
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<td>P</td>
<td>P</td>
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<tr>
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<td>M</td>
<td>P + Coop</td>
<td>P + Coop</td>
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<td>Market</td>
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<td>I</td>
<td>P + Coop</td>
<td>P + Coop</td>
<td>P + Coop</td>
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<td>G + Domes</td>
<td>G + Cons</td>
<td>G + Coop</td>
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<td>G + Domes</td>
<td>G + Cons</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Market</td>
</tr>
</tbody>
</table>

| Codes: G | Predominantly Government Enterprises, Agencies, and Institutions (e.g. 99% or more) |
| P | Predominantly Private Enterprises, Individuals, and Institutions (e.g. 90% or more) |
| IV | Joint Ventures between Government and Private |
| M | Mixed Government and Private Involvement (e.g. significant but separate roles for each) |
| Coop | Seed to Producer Coop |
| Coop | Government encouraging seed to private firms or farmers |
| N.A. | No formal activity |
Rice Seed Industries

4.16 Table 4 depicts the institutional mix for rice seed development, production, and marketing in major rice-producing countries in Asia, a region which accounts for more than 90% of the world's rice-growing area. Among the listed countries there are wide differences in the extent to which high-yielding varieties have spread and in the importance of commercial seed in the total rice seed use. While in China, Bangladesh, and Thailand HYVs accounted for 30% or less of the planted area in 1988, in Indonesia, Japan, and the Philippines, HYVs covered 70% or more of the area. The proportion of total seed use which is accounted for by commercially purchased seeds is 15% or less in India, Thailand, Bangladesh, and the Philippines, between 25% and 30% in China and Indonesia, and a significant 72% in Japan.25

These different patterns, especially that regarding the importance of commercial seed in meeting annual seed requirements, should be kept in mind when examining the relative roles and market shares of the private and public sectors in the supply of rice seeds. In India, Thailand, Bangladesh, and the Philippines, both private and public sector enterprises play a relatively minor role in meeting annual seed requirements, with farmer seed retention and informal exchange arrangements being dominant.

4.17 Table 4 indicates that rice seed imports at commercial levels do not occur for the majority of listed countries as a result of local production, government restrictions on imports, and the very low value/bulk ratio for rice seeds. Only in Thailand, where basmati varieties are imported for specialized production, are private firms involved in this activity. Varietal development for rice is a public sector activity conducted both in (national and international) research institutes and universities. In most of these countries, rice is the strategic crop of public agricultural research given its importance for food security. In recent years, private research activity in rice has expanded in Japan, with several firms exploring opportunities for hybrids. Private sector research on hybrid rice has also begun in India.26 Foundation seed production is undertaken on state farms in all of the countries except Japan where breeder seed of public varieties is supplied to cooperatives for multiplication and further commercial

25 Information on the spread of HYVs is from IRRI World Rice Statistics 1990. Information on the share of seeds used which are supplied commercially was obtained from Delouche (1990), Pray (1990), and FAO/World Bank (1991).

26 See Pray (1991) for a review of recent changes in rice research in Asia.
development. In Indonesia, some foundation seed production is contracted out to farmers, while in India some foundation seed is produced privately by small companies multiplying public varieties. Given the importance of rice as a basic food staple in most of the listed countries, where private firms or farmers do participate in seed production, they are certified or monitored by farmer associations and/or state agencies.

4.18 The rice seed systems for both China and Bangladesh feature a dominant or exclusive role for the public sector. For the other developing countries included in the table, seed systems feature a combination of public and private sector participation. The commercial viability of private seed production and distribution for self-pollinated rice in these countries stems from several factors, including: 1) the steady stream of improved varieties generated by public research institutions which farmers have readily experimented with, 2) the uneven quality of seed distributed by public seed enterprises providing an opportunity for private firms which can develop a reputation for delivering quality seed, and 3) the very large volumes of seed required from commercial sources even though replacement rates are relatively low.

4.19 Nevertheless, with the exception of Thailand, the public sector continues to account for a majority of certified rice seed production and sales in these countries. In pursuit of food security objectives, most of the governments within the region built up, frequently with bilateral or multilateral donor assistance, large-scale and centralized rice seed production, processing and distribution systems. In many cases, public sector seed has been subsidized and public credit programs have linked the supply of credit with the purchase of HYV varieties from public sources (e.g. 'no seed, no credit').

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27 See Delouche (1990) and Pray (1990). In Thailand, government distribution of rice seeds is primarily focused on emergency relief and does not constitute a commercial activity.
Table 4: Rice Seed Systems in Major Asian Producing Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Direct Seed Import</th>
<th>Variety Development</th>
<th>Seed Production/Processing</th>
<th>Seed Marketing/Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Foundation/Basic Seed</td>
<td>Wholesale/logistics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Commercial/Certified Seed</td>
<td>Promotion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Seed Processing</td>
<td>Retail sales</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>Price determination</td>
</tr>
<tr>
<td>China</td>
<td>NA</td>
<td>G + IRRI</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>G</td>
<td>G</td>
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<td></td>
<td></td>
<td></td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>India</td>
<td>NA</td>
<td>G</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CON + P</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Indonesia</td>
<td>NA</td>
<td>G + IRRI</td>
<td>G + CON</td>
<td>M</td>
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<td></td>
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<td>M</td>
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<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Thailand</td>
<td>P</td>
<td>G + IRRI</td>
<td>G</td>
<td>M</td>
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<td></td>
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<td>CON + P</td>
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<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>G</td>
<td>G + IRRI</td>
<td>G</td>
<td>G</td>
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</tr>
<tr>
<td>Japan</td>
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<td>Coop</td>
<td>Coop</td>
</tr>
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<td></td>
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<td>Coop</td>
<td>G + Coop</td>
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<td></td>
<td>Coop</td>
<td>Coop</td>
</tr>
<tr>
<td>Philippines</td>
<td>G</td>
<td>G + IRRI</td>
<td>G</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CON + P</td>
<td>M</td>
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<td></td>
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</tr>
</tbody>
</table>

Codes:  
G Predominantly Government (Public) Enterprises, Agencies, Universities, and Institutes (eg. 90% or more)  
P Predominantly Private Enterprises, Individuals, and Institutes (eg. 90% or more)  
M Mixed Government and Private Involvement (eg. significant but separate roles for each)  
Coop Seed or producer cooperative.  
CON Government contracting out to private firms or farmers.  
* Public sector seed is subsidized.

(Sources: Author's Seed Survey; FAO/World Bank (1991); Ribeiro (1991); Pray (1991)
Maize Seed Industries

4.20 Table 5 depicts the public-private sector mix of activities for hybrid maize seed development, production, and distribution. The table indicates that among the sampled countries the role of the private sector is of greater relative importance than in the cases of wheat and rice. Such patterns are consistent with the predictions of economic theory. Imports of hybrid maize seed occur for many countries. With the single exception of Bangladesh whose imports by government agencies are very small in scale, such imports are undertaken either by the private sector or a combination of private and public firms with multinational seed companies serving as the primary suppliers.

4.21 In most of the countries in the sub-sample, varietal development work for hybrid maize is undertaken both by the public and private sectors and in some cases (eg. Kenya, Egypt and Ethiopia) by public/private joint venture companies. For all countries where such work is undertaken the private sector has participated. In many developing countries, the lead role in varietal development and testing has been taken by multinational companies, drawing upon their global supplies of germplasm and scientific resources. Much of their research has involved adaptive, observational tests of varieties developed elsewhere, although in some countries new varietal development is being done. Because of the considerable financial and scientific resources required to successfully develop hybrid maize varieties, the indigenous private firms which have undertaken applied research have tended to be medium-to-large-scale companies, frequently with diverse agricultural or industrial interests.28

4.22 Private research on hybrid maize as well as hybrid varieties of other major foodgrains (eg. sorghum and millet) in developing countries has frequently depended upon support from the public sector particularly in the supply of germplasm and inbred lines and in the training of scientists. Local companies not linked to multinational firms generally rely upon international and/or national public agricultural research centers as sources of improved genetic material. Such genetic material is often supplied free or at very low cost providing an implicit subsidy for private varietal developers. In some countries, private firms have been provided with tax benefits on their investments in plant breeding. For example, in India firms designated as R&D Centers are permitted to write off for tax purposes their capital investments in research facilities and equipment.

28 In a survey of private companies undertaken foodgrain seed research and production in India, Pray et al. (1989) found that those firms which undertake R&D have average annual seed sales of Rs 34 million compared with only Rs 2.6 million for firms which do not undertake R&D.
<table>
<thead>
<tr>
<th>Country</th>
<th>Variety Sourcing/Development</th>
<th>Seed Production/Processing</th>
<th>Seed Marketing/Distribution</th>
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</thead>
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<tr>
<td></td>
<td>Direct seed import</td>
<td>Foundation Seed</td>
<td>Commercial Seed</td>
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<td>DEVELOPED ECON</td>
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<td>P</td>
<td>M</td>
<td>P</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>France</td>
<td>P</td>
<td>M</td>
<td>P + Coop</td>
</tr>
<tr>
<td>Italy</td>
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<td>P</td>
<td>P + Coop</td>
</tr>
<tr>
<td>Japan</td>
<td>P</td>
<td>M</td>
<td>P + Coop</td>
</tr>
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</tr>
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<td>M</td>
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<td>Ecuador</td>
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<td>ASIA</td>
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<tr>
<td>India</td>
<td>P</td>
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<td>M</td>
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<td>Bangladesh</td>
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<td>N.A.</td>
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<td>Philippines</td>
<td>P</td>
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<td>M</td>
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<tr>
<td>Thailand</td>
<td>P</td>
<td>P</td>
<td>P</td>
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<td>NEAR EAST</td>
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<td>G + IV</td>
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<td>Zimbabwe</td>
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<td>M</td>
<td>M</td>
</tr>
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<td>Kenya</td>
<td>N.A.</td>
<td>IV</td>
<td>IV</td>
</tr>
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<td>M</td>
<td>IV</td>
<td>IV</td>
</tr>
<tr>
<td>Togo</td>
<td>M</td>
<td>P</td>
<td>P + Coop</td>
</tr>
<tr>
<td>Nigeria</td>
<td>N.A.</td>
<td>M</td>
<td>P</td>
</tr>
</tbody>
</table>
4.23 In developed market economies, all commercial activities associated with production and distribution of hybrid maize seed are handled by the private or cooperative sector. Among developing countries, institutional patterns vary. In such countries as Mexico, Ecuador, Bolivia, India, Indonesia, Egypt, and Tanzania, public, private, and cooperative organizations co-exist, either competing with one another or serving different market segments. The public seed corporations participating in this market have frequently benefitted from preferential access to varieties developed by national research institutions and from guaranteed market outlets via agricultural projects or credit programs (See Case Study #3). Their continued participation in this market even after the emergence of a vibrant private sector (e.g. in India and Mexico) stems from the need to cross-subsidize losses incurred in the development and sale of high-volume, low-value self-pollinated crop seeds as well as latent concerns about the possibility that multinational companies will dominate the local seed market. In Egypt, a public agency handles the wholesaling and promotion of nearly all hybrid maize seed, even that produced by the private sector. This is not due to restricted entry, but to the agency's nation-wide distribution facilities and its low (government subsidized) trading margins, together with the underdevelopment of the private sector.

4.24 In other developing countries, hybrid seed production and trade is conducted either entirely by the private (and/or cooperative) sector or by joint venture companies involving private and public sector interests. The degree of competition among such firms varies considerably. In the case of Zimbabwe, a seed cooperative has a virtual monopoly over the production, processing, and wholesaling of hybrid maize and has developed a distributor network to supply farmers (See Case Study #4). In Kenya, the joint venture Kenya Seed Company has a virtual monopoly over the local hybrid maize market with protection against competing (foreign) firms justified on the basis of food security considerations. In contrast, in such countries as India and Thailand, a dozen or more foreign and local companies compete in the hybrid maize seed market, utilizing hundreds of distribution outlets. The competition in these markets has been a major stimulus for expanded private sector investment in R&D. Price controls or subsidies are far less common for hybrid maize than for wheat or rice. The exception to this is in sub-Saharan Africa where price regulations are still widespread.

4.25 In the early stages of hybrid maize seed market development, the focus of the private sector has typically been on supplying seed to larger commercial farmers or to the domestic animal feed industry operating in high potential areas. Predicting seed demand for such segments is relatively
straightforward, while the logistical problems and transaction costs associated with serving this market are lower than for serving smallholder farmers. The adoption of hybrids has typically been faster amongst such segments given their dominant concern with yield performance as opposed to the taste or processing characteristics of the grain. Still, once seed demand from the commercial sub-sector is satisfied and as seed markets become more competitive, private producers and distributors of hybrid maize (and other hybrid foodgrain) seeds have directed their attention to smallholder farmers and rainfed areas (See Case Studies 2+3).

4.26 While Table 5 indicates that private sector participation is widespread in hybrid seed industries, it must be emphasized that hybrid varieties of maize are well established in relatively few developing countries. To assess the significance of private sector production and sales activities, it is important to place hybrid seed sales within the overall context of maize seed markets. Unfortunately, only a 1985-86 maize seed survey conducted by CIMMYT generated data which can be used for this purpose. Table 6 shows the value of hybrid maize seed compared with farmer-saved and improved open-pollinated varieties in a sample of developing countries, together with the private sector’s share of the markets for OPV and hybrid seeds, and the overall shares of the private sector, public sector, and farmer-saved sector in the total value of maize seeds used.

4.27 The following major points can be drawn from the table and the data base upon which it was derived:

1) hybrid seeds account for the three-fourths of maize seed value in Latin America, slightly more than one-half of such value in Asia and the Near East, but only one-fourth of the value in Africa. Relatively large maize seed markets in which hybrid varieties account for one-third or less of seed value include Mexico, Bolivia, India, the Philippines, Indonesia, Thailand, Tanzania, and Nigeria. It is in such countries where the opportunities for private sector expansion of maize seed production and distribution are substantial.

2) the commercial value of improved open-pollinated varieties is insignificant with the exceptions of Mexico, Brazil, the Philippines, Thailand, and Nigeria. The share of the private sector in the sales of such varieties is high is each of these countries other than the Philippines. For the full sample of countries, the private sector’s share ranges from 0 in China, Syria, Turkey, Afghanistan, Ghana and Ethiopia to 100% in Chile’s and Zimbabwe’s minuscule market for open-

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29 The low share of the private sector in the Philippines can be attributed to the dominant role of multinational corporations within the private sector there. The focus of these MNCs has been almost exclusively on supplying hybrid maize seeds to the feed industry. In the other listed countries, locally-owned private firms are more active in the maize seed market.
pollinated varieties. For all developing countries, the private sector's aggregate share of OPV sales was 63%. Hence, even though full exclusion is not possible, private firms can profitably sell OPVs of maize, especially in large markets or in conjunction with their other sales of hybrid varieties.

3) the share of the private sector in sales of hybrid varieties ranged from 0% in Syria and China to 100% in several countries. By region, the private sector's share was 95% or more in Latin America and Africa, 62% in non-communist Asia, and only 42% in the Near East. Taking all developing countries together, the private sector's share was only 41%, yet when removing Communist countries this share rises to 92%. Despite the wide participation of the private sector, public enterprises remain active in hybrid seed sales in Mexico, India, and Turkey.

4) when including farmer-saved seed, the share of private firms in the total value of maize seeds used ranges from 0 in several countries (e.g. China, Syria, Ghana) to 90% or more in Argentina, Chile, and Zimbabwe. The private sector's share is relatively high in Latin America with a weighted average of 74%. In the other three regions the private sector's share is one-third or less of the total (potential) market. In both Africa and non-communist Asia, nearly two-thirds of the value of seed is farmer-saved, while in the Near East, the public sector accounts for the largest proportion. Among the twenty-one listed countries, the public sector accounted for one-third or more of the total maize seed value in only five countries. The core issue facing many developing countries is thus not the privatization of existing formal maize seed activities and facilities, but the overall development or expansion of commercial seed systems. This is especially true in Africa and in such large countries as Indonesia and Egypt.

**Vegetable Seed Industries**

4.28 Table 7 depicts the institutional patterns for vegetable seed industries in the sub-sample of countries. As expected, the private sector participates in most aspects of vegetable seed production and distribution and has a predominant role in such activities in approximately one-half of the sample. The importation of vegetable seed is very common as many countries (including some industrialized countries) have not developed local vegetable seed production. The table indicates that such imports are normally undertaken by private firms. These firms either multiply the seeds, repackage them, or distribute them directly.

4.29 Although far less active in commercial activities for vegetable seeds, the public sector is active in varietal development work in nearly all of the sampled countries. Typically, public sector research has focused on non-hybrid varieties of common vegetable crops, while private sector research has focused on hybrids and specialties. Still, the level of such varietal development work is very limited in most developing countries with the size of domestic demand being too small to support
<table>
<thead>
<tr>
<th>Region/Country</th>
<th>Value of Farmer-Saved Seed ($ Mill.) (A)</th>
<th>Value of Commercial OPV Seed ($Mill) (B)</th>
<th>Value of Commercial Hybrid Seed ($Mill) (C)</th>
<th>Private Sector Share of OPV Sales (%) (D)</th>
<th>Private Sector Share of Hybrid Sales (%) (E)</th>
<th>Farmer Share of Total Seed Value (%) (F)</th>
<th>Private Sector Share of Total Seed Value (%) (G)</th>
<th>Public Sector Share of Total Seed Value (%) (H)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mexico</td>
<td>20.5</td>
<td>5.9</td>
<td>13.0</td>
<td>62</td>
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<td>52</td>
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<tr>
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<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
</tr>
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a full-fledged varietal development program. While public sector corporations participate in selected vegetable seed production and distribution in many developing countries, their market shares are typically very low as private firms tend to be more flexible and thus better able to serve diverse farmer horticultural seed needs. Public sector vegetable seed production and trade has frequently been undertaken in the context of specific (donor-financed) projects, in pursuit of import-substitution, or to support export-oriented horticultural industries. With the single exception of Ethiopia which has sought to regulate prices, vegetable seeds are sold at market-determined prices.

4.30 Vegetable seed production and trade has often been the initial line of activity for small-to-medium scale indigenous seed companies in developing countries. The highly diverse demand patterns for such seeds and the careful husbandry required in their production has given such firms a competitive advantage. In later stages of seed industry development in several countries, the private sector has played a central role in 'custom' horticultural seed production, supplying local processors or overseas buyers with commercial seed of particular varieties (See Case Study 6).

Seed Systems in Transition

4.31 Tables 3 through 7 provide a snapshot of the current or recent division of public and private sector roles in the development, production, and distribution of seeds for a range of major crops. It is also important to consider the institutional changes which occur as seed systems develop and evolve as well as the problems which are commonly encountered in the transition from state-dominated seed systems to more competitive systems featuring a greater role for the private sector. Such themes are examined in the case studies section, particularly those concerned with the seed systems of India (Case Study #2), Mexico (#3), Zimbabwe (#4), and Ethiopia (#5). Brief comments on some of the major issues raised in these case studies follow.

Case of Ethiopia

4.32 Even though considerable progress has been made over the years in the development of improved varieties for major crops, the overall Ethiopia seed system remains at an early stage of commercial development. It is estimated that seeds supplied by the formal sector account for only 5% of total seed use in the country. Through the implementation of individual seed projects and the establishment (in 1978) of a state seed corporation (Ethiopia Seed Corporation), the formal seed sector has been dominated by the public sector at all levels of activity including seed multiplication
and distribution. This public seed system has not been commercially oriented. For many years, the ESC was primarily oriented to serving state farms and largely neglected the peasant sector. A large proportion of seed sales have gone to state farms at government-determined prices. The ESC and the seed-producing farms have incurred steady losses, and in the face of a collapsing state farm sub-sector, the production and distribution of seeds has declined. A national seed policy has yet to be developed.

4.33 Beginning in 1988, the Ethiopian Government embarked upon a gradual program of reform within the agricultural sector and the wider economy. Important elements of this reform program have been efforts to increase the managerial autonomy and accountability of public enterprises and to liberalize production, pricing, and trade for agricultural commodities and inputs. In the seed sector, one result of the more liberal economic environment was the development of a joint venture between the ESC and Pioneer Hi-bred International. The joint venture will concentrate on developing, producing, and marketing hybrid varieties of maize, sorghum, and sunflower, and some vegetable and forage crops.

4.34 The ESC-Pioneer joint venture is unlikely to have much of an impact on seed availability to and farm productivity within the smallholder sub-sector for several years. Responsibility for developing and producing self- and open-pollinated varieties of major food crops (e.g., tea, barley, wheat, pulses) will remain predominantly with public research institutes and the ESC. Whether or not the joint venture has a stimulatory effect on the development of a wider seed industry will depend upon the institutional arrangements it makes for seed multiplication and distribution. If such activities are monopolized by the firm, then wider institutional development will not occur. A proposed (World Bank-supported) National Seed Project has been designed to further develop the formal and informal seed systems and to expand private sector participation within it. Among the proposed measures are: the decentralization of ESC operations, a program to contract out commercial seed production to smallholder farmers, pilot projects to support private seed enterprises, and support for village-level informal seed activities. The project will also promote the development of a national seed policy and capacity-building for breeder seed production, quality control, and seed market assessment. The ESC will increasingly adopt a commercial orientation. The implementation and success of this project will depend in part upon wider political developments and economic reforms in the country.
The Case of Zimbabwe

4.35 The Zimbabwe seed system operates in sharp contrast to that of Ethiopia and to those of most other African countries. Not only does Zimbabwe have a relatively well functioning commercial seed industry, but this industry has featured a dominant role for the private and cooperative sectors in seed production and distribution. Zimbabwe has been very successful in developing and distributing hybrid and improved varieties of the major food crop -- maize, and the countries leading industrial crops—cotton and tobacco. While supply systems for such seeds were once confined to the large commercial farm sub-sector, since independence the spread of improved varieties for such crops has been almost universal within the smallholder sub-sector. Nevertheless, until now Zimbabwe’s seed system has failed to develop or produce sufficient quantities of improved seeds for a wide range of other food and industrial crops, including food legumes, groundnut, oilseed crops, and horticultural crops. Such seed development and production gaps have contributed to the food security problems faced in smallholder areas and have constrained efforts at agricultural export diversification.

4.36 The structure of the Zimbabwe seed system is relatively unique. For most crops, the government has entered into long-term agreements with farmer cooperatives, giving the latter exclusive control over publicly released varieties and licenses to multiply and distribute seeds of such varieties. The seed cooperatives (comprised mainly of large-scale farmers) and the government annually negotiate the levels of production and the prices to pay producers and charge consumers. One organization, Seed Co-op, subsequently controls 95% of the major commercial seed market, that for hybrid maize. The second largest seed market, that for cotton, is monopolized by the parastatal Cotton Marketing Board although the organization does contact outgrowers to produce the seed.

4.37 The major challenge facing the Zimbabwe seed industry is to diversify the range of improved crop varieties being developed and commercially sold and to extend distribution systems to smallholder farmers beyond the existing lines for hybrid maize. While the monopoly public/private alliance proved effective in the development of the hybrid maize seed industry, it is likely that the designation of exclusive access to public varieties for particular crops to a limited few producer groups has not only resulted in insufficient investment in other seed crops, but has also inhibited the wider development of private sector seed production and trade. Recently this trend has been partly reversed by the decision to allow a multinational seed company, Pioneer Hi-bred Int’l., to operate in Zimbabwe.
The Case of India

4.38 The seed system of India is one of the more advanced among developing countries. It is a system of major contrasts. While hybrid varieties of maize, sorghum, pearl millet, cotton, and sunflower have been successfully developed and spread over relatively large areas during the past quarter century, commercially sold seed still accounts for less that 10% of total seed use, with farmer-saved seed of self- and open-pollinated varieties remaining dominant. The seed system features a complex mix of public and private sector institutions whose activities are sometimes complementary and other times competitive or overlapping.

4.39 Over the past three decades, major investments have gone into the development of public seed production, processing, and distribution systems at the national and state levels. Public seed corporations have been supply- rather than commercially-oriented. They have sought to prevent 'shortages' of seed, yet have not developed realistic assessments of actual seed demand. Their operations have frequently been driven by political and interest group pressures. While public sector production has expanded considerably, this has required huge government subsidies. There has also been a considerable duplication in investments and activities of state and national seed corporations. While the public seed corporations have concentrated most of their activities on the production and sale of self-pollinated crops, some such corporations have also been active in the market for hybrid varieties of maize and other crops, partly to subsidize their losses from other seeds.

4.40 Over the past two decades, private sector seed production and distribution has expanded considerably, albeit slowly. As a result of restrictions on landholdings, germplasm and technology imports, foreign ownership, and the size of domestic companies permitted to participate in the seed industry, most of the private firms which entered the industry during the 1960s and 1970s were small-to-medium-scale. Lacking resources to undertake their own research, these firms concentrated on multiplying and distributing public hybrids and improved varieties. With changes in investment and industrial policies and with a liberalization of external trade in seeds in 1988 and 1991, there has been a large increase in foreign and domestic private investment in seed-related activities. Several of the larger entrants have invested in plant breeding of hybrid varieties, drawing upon either Indian public sources or foreign sources of germplasm and inbred lines. The government and public universities have provided technical and/or financial support to several such ventures. Smaller private companies have been successful in multiplying and distributing public varieties of self-pollinated seeds.
With the growing strength of the private sector, the future viability of some loss-making state seed corporations is in doubt even though the potential for future seed market growth in India is considerable. In some cases, a redefinition of the roles of the public seed corporations will be required with future activity focusing less on commercial seed production and distribution and more on foundation seed production and the provision of technical and other support to private firm or informal seed multiplication activities. Public sector duplication of private sector development, production, and distribution of hybrid varieties should be avoided. Joint research projects between public institutions and the large seed companies can be undertaken. This redefinition of the roles for public sector institutions will entail major adjustments in their ways of operating and may require the re-assignment or redundancy of personnel and facilities.

The Case of Mexico

The seed system of Mexico is also among the more advanced in developing countries. In contrast with India, there is a high level of commercialization for many seed crops, including sorghum, wheat, soybean, vegetables, and fodder crops. The seed system features a mix of relatively significant public, private and cooperative sub-sectors among which cooperation has been far less than in the case of India.

The transition problem faced in Mexico is similar in some respects to that in India. The state seed corporation, PRONASE, has been built up over the past quarter century through near exclusive access to improved public varieties, government subsidies, and a guaranteed market for much of its production via a public credit system. The private sector, especially the local private sector, was held back by restrictions on trade and the transfer of varieties and germplasm from public research institutes. With the liberalization of trade and investment laws in the 1980s, there has been a significant amount of foreign and joint venture investment in seed development, production, and distribution. Most of this activity has focused on hybrid varieties and specialty crops, areas in which the private sector is now dominant. The larger firms have focused on supplying seed to the commercial farm sub-sector in irrigated and high potential areas. The cooperative sector has been successful in multiplying and distributing public varieties of self- and open-pollinated crops.

With the passage of a new seed law in 1991, PRONASE’s exclusive access to public varieties has been lifted. This and changes in credit policies to allow farmers to procure seeds from any
available source should contribute to an expansion in the local private sector. With the larger foreign and joint venture firms expanding their production of hybrids and with the strengthening of the cooperatives, the potential commercial role for PRONASE will be considerably narrowed. An important function will remain the production of breeder, foundation, and commercial seed production for self- and open-pollinated crops. PRONASE's primary role could be providing technical, organizational, and financial support to programs geared toward the contracting of such production. This transition from a producer/distributor to a promoter/regulator will entail a major rationalization of PRONASE's infrastructure and personnel.

V. Conclusions and Policy Implications

5.1 Seeds are the single most important input in all plant-based agricultural systems. Seeds determine the upper limit on yield potential and therefore the ultimate productivity of other inputs. While seeds are the carriers of the genetic potential of the crop plant, other inputs simply build the environment enabling the plant to perform productively. The production and distribution of seeds is potentially the lowest cost means of transferring technology in agriculture.

5.2 An important characteristic of seed is its ability to reproduce itself. Seeds can be an agricultural output in one period, used as an input during a subsequent period. This characteristic enables farmers to serve as their own seed suppliers, setting limits on the development of a commercial seed market. Any analysis of the appropriate roles for the public and private sectors in seed development, production, and distribution must begin with a recognition of what seed-related functions farmers can and cannot perform efficiently (Pray and Ramaswami 1991).

5.3 Skilled farmers can efficiently produce and store seeds of major self-pollinated crops (eg. rice and wheat), with the replacement of such seed being required only after four or more years. Although facing somewhat greater risk of genetic or quality deterioration, farmers can also reproduce and maintain some varieties of open-pollinated crops (eg. maize, sorghum). Farmers can test different varieties in their fields, selecting those which perform well according to yield and other criteria. Farmers can effectively learn from or inform their relatives or community members about new varieties and improved methods for seed production and storage. Farmers can exchange seeds on a small scale with such relatives or community members.
However, farmers are generally neither technically nor financially capable of conducting plant breeding research. They cannot produce hybrid seed as they do not have access to inbred lines as it is a sophisticated operation. When retaining planting materials for crops which are vegetatively propagated, farmers encounter risks that plant diseases will develop and spread. They frequently encounter technical barriers and incur considerable costs when attempting to produce many types of vegetable and forage crop seeds. Individually, all but very large-scale farmers cannot achieve economies of scale in seed processing and cannot trade new varieties or higher quality seed over long distances.

5.4 These generic principles have several important implications for the development and organization of seed supply systems:

First, farmers should not be viewed simply as the 'consumers' of the output of seed supply systems. They are frequently core participants in such systems, acting as seed multipliers, storers, and distributors, variety testers, and information suppliers, in addition to being the final users of seed. Farmers can play major roles in seed systems by producing and retaining their own seeds and by serving as contracted producers or distribution agents for formal research or seed institutions.

Second, the development of new varieties of crops, the production and distribution of hybrid varieties, the production and distribution of seeds for many vegetables, forages, and vegetatively propagated crops, and the distribution or exchange of seeds over large distances will normally require investments and management by formal and specialized research, seed, or trade organizations, either in the public or private sectors.

Third, in most developing countries only a small proportion (e.g. 5-20%) of the total seed required for self-pollinated crops will be supplied by formal seed or trading enterprises, with the bulk of supply coming from farmer retention or farmer-farmer exchanges. The necessary role of formal seed enterprises is to provide the initial seed of new improved varieties of such crops and to provide high quality replacement seed in the amounts and at the times required.

5.5 Of these three institutional principles, both the first and the third have been poorly factored into most seed sector interventions by governments and donors in developing countries over much of the past two decades. Faced with pending food security pressures, lacking confidence in the capacity of farmers or private firms to meet national seed requirements, and drawing upon high input and management-intensive models of seed propagation from industrialized countries, many developing country governments and donors invested in the development of large-scale national and state seed corporations and state seed farms to multiply and distribute improved seeds of major crops.
Many national seed programs have set seed production targets, with the public corporations proceeding to pursue such targets, frequently at the expense of quality and usually in the absence of any realistic assessment of current or future demand. While these public seed systems did play an important role in the initial spread of high-yielding varieties of major food crops in several countries, most public seed corporations which have retained a major role in commercial seed production and distribution have operated at well below capacity and have been a major financial drain on governments. None of these organizations has been able to meet the diverse crop and varietal needs of different categories of seed users. Until quite recently, insufficient attention was given to the potentially important roles which farmers, private firms, and other non-governmental organizations might play in seed supply systems and to the alternative ways of organizing seed production and distribution, both within the public and private sectors. Most interventions have been ad hoc, undertaken in the absence of a national seed policy and seed system development strategy.

5.6 This study has sought to provide an analysis of the appropriate and actual mix of public and private sector roles in seed development, production, and distribution. Here, we summarize the major findings and indicate possible interventions by governments and donor agencies which can promote the further development of seed supply systems and achieve a more efficient mix of public and private sector roles within such systems.

VARIETAL DEVELOPMENT

5.7 While some forms of plant breeding R&D can be a profitable activity for private firms, economic theory suggests that the amount of investment by the private sector in such activity will not be at socially optimal levels. This is due to the fact that plant breeding R&D is very costly and risky, entails long gestation periods, gives rise to potentially significant externalities, and has outputs which have the public good properties of non-exclusivity and non-rivalry.

5.8 The significance of these factors has been shown here to vary across different types of commodities. In the case of hybrids, plant breeders are frequently able to exclude non-paying users and thus appropriate a sufficient proportion of the benefits from such varieties to make investment in breeding profitable. However, plant breeding work for hybrid varieties is especially difficult from a technical point of view, entails considerable cost, and is a long-term venture. In contrast, plant
breeding work for self- and open-pollinated varieties is less costly and requires shorter lead times, yet
the scope for the breeder to appropriate the benefits from such R&D may be very limited.

5.9 Because of the high investment costs, economies of scale, high risks, and uncertain payoffs from
plant breeding R&D, such work has been undertaken by the public sector (e.g., research institutes and
universities) throughout the world, with financing coming from taxpayers and foundations. The public
sector has been especially dominant in R&D for self-pollinated crops. Private sector plant breeding,
both in industrialized and developing countries, has focused on developing hybrid varieties of major
crops for which the scope for appropriating benefits is relatively high. The firms undertaking such
research have usually been large in scale, with the bulk of private research in many developing
countries being undertaken by multinational or joint venture companies.

5.10 Experience from many countries indicates that public research (including that at international
research institutes) and public support for private sector varietal development can lead to efficiency
gains. This is especially the case in the early stages (e.g., Stages 1 and 2) of seed system development
when the supply of trained seed technicians is inadequate, the financial resources available for
research are very limited, and great uncertainty about the technical and commercial outcome of plant
breeding R&D prevails. In these early stages, public sector research will normally be dominant,
although individuals trained at public research institutions may subsequently enter the private sector.
Any private investment in plant breeding R&D which occurs at these early stages will normally be
confined to investments by international or joint venture companies in hybrids for a narrow range of
crops. While such investments should be encouraged because of their potential demonstrative effects,
they are likely to play only a marginal role in the seed supply systems at these stages of development.

5.11 At intermediate or advanced stages, when the private sector has started research programs,
public sector support can further stimulate it and increase its efficiency. By conducting basic research
and by providing germplasm and technical training, public institutions can lower the costs of entry for
private firms in R&D and stimulate competition within the sector. When the public sector conducts
research on hybrids and makes available inbred lines to private firms, it can greatly reduce the time
period needed by the latter to develop finished varieties. Joint research projects between public and
private institutions can increase the resources available to each and improve performance. The
recognition and enforcement of plant breeders rights may stimulate private investment in plant
breeding for self-pollinated crops in more advanced seed industries, although empirical support for this proposition remains limited.

**Seed Production and Processing**

5.12 The multiplication and processing of seed also features externalities, risks, and 'public good' characteristics, although these are generally of lower magnitude than in the case of plant breeding R&D. While some economies of scale can be realized, especially in processing, their significance is again lower than in the case of plant breeding. For many types of seeds, entry barriers to such activities are thus much lower, and opportunities for profitable investment more widespread.

5.13 Important externalities do exist with respect to the multiplication of foundation seed, as this seed will subsequently be used over a wide area to produce commercial seed. The loss of genetic or physical purity in foundation seed will have adverse multiplier effects on the subsequent production of commercial seed and on seed marketing efforts. Production risks will be high when multiplying a new variety and when seed multiplication occurs in drought-prone areas or under agro-ecological conditions different from those for which the variety was bred. Scale-economies do exist in seed production of some field crops for which planting, harvesting, or other functions can be mechanized; they do not exist for most horticultural crops and hybrids given their heavy labor and management requirements. Where the market for seed is developing, opportunities for profitable multiplication and processing of hybrid varieties, improved open-pollinated varieties, and seeds of specialty crops may be significant. Potential profit margins are much lower for the multiplication and processing of seeds for self-pollinated crops, since specialized producers will have to compete with low-cost farmer production and retention.

5.14 A survey of seed supply systems in industrialized and developing countries does indeed indicate widespread participation by the private sector in seed multiplication and processing. In very advanced seed systems, the private sector, comprised of large companies, producer/seed cooperatives, and small, localized companies, dominates these activities across the full range of crops. The private sector even dominates the multiplication of foundation seeds of public varieties of self-pollinated crops.
5.15 In most seed systems still in early to intermediate stages of development, the leading and sometimes dominant seed producers are farmers themselves. Farmer-saved seed or seed saved and exchanged within local communities account for 80% or more of the seeds used in most developing countries. Nevertheless, much of this seed is derived from seeds initially introduced by the formal (primarily public) seed sector. Seed supplies from formal sub-systems frequently feature a mix of public and private sector roles in production and processing. Public sector involvement is most widespread and intensive in the production of high-volume self-pollinated crops, such as rice and wheat. This involvement is significant both in foundation seed and commercial seed production.

However, in many countries, especially those whose seed systems have reached at least an intermediate stage, a large and growing proportion of publicly financed commercial seed production is done by contracted farmers in their own fields. The production and processing of hybrids and of horticultural and forage crop seeds is undertaken by private firms and/or cooperatives in many developing countries, with the private sector frequently accounting for a dominant market share for such seeds. Some of this activity is undertaken on a vertically-integrated basis; other activities are performed on a highly specialized basis or involve firms contracting out particular functions to farmers or other firms.

5.16 As in the case of plant breeding, public interventions in seed production and processing can yield efficiency gains. Such interventions are most vital in the early stages of seed system development. In such early stages, there may be inadequate information about the risks and benefits of seed multiplication as well as inadequate knowledge about the techniques of doing so or of processing seed. At these stages, public sector production of foundation seed for many crops will be necessary. Where investments by private firms in subsequent commercial seed production and processing are slow to develop, the public sector may need to undertake a crash program also, although this need not involve centralized, state farm production. Public agencies should contract out commercial seed production and should encourage the formation of farmer seed associations/cooperatives to organize such production. In the early stages of seed system development, governments can assist farmer and private firm seed production and processing by: 1) supporting seed multiplication pilot projects, 2) training seed technicians, 3) supporting informal, village-level seed multiplication activities, 4) providing financial and technical support to firms producing seed processing equipment, and 5) purchasing the seeds multiplied and processed by private firms.
5.17 At intermediate or advanced stages of seed system development, public sector production and processing of commercial seed cannot be justified on efficiency grounds since the private sector will have the interest and capability to perform such activities and can normally do so more efficiently than public enterprises. Still, equity considerations may lead the government to produce or subsidize the production of seeds for minor crops or varieties suitable for narrow agro-ecological areas or disadvantaged areas.

5.18 Where extensive public sector facilities for commercial seed production and processing were built up at earlier stages, such facilities should either be leased or sold to the private sector (once private production and trade has become sustainable) or converted for alternative uses. Personnel trained for and experienced in the management of state seed farms should be retrained to enable them to effectively advise private seed companies, advise informal, village-level groups, or organize and monitor seed outgrower schemes. Otherwise, such personnel should be encouraged to join or start their own private seed companies without loss of personnel benefits from public service.

5.19 At intermediate stages, public sector research institutions should continue to supply breeder seed and public seed enterprises should focus on the production of high quality foundation seed of self- and open-pollinated varieties. While such production could be done at universities or public research institutes, this would likely detract from the most effective use of the limited supply of plant breeders and seed technicians. Foundation seed production on state farms might gradually give way to contracted production with designated seed companies or associations. The foundation seed should then be made available to a wide range of private and cooperative seed multipliers to stimulate competition. Seed processing should be decentralized in line with the decentralization of production, with the facilities of public seed corporations being leased or sold to cooperatives or private firms.

Seed Marketing and Distribution

5.20 The marketing and distribution of seed entails several inter-related components and functions, including market research, demand promotion, seed storage and transport, seed distribution, and seed pricing. While each of these activities is potentially profitable for the private sector, the performance of several such functions is associated with economies of scale, externalities, and/or 'moral hazard' problems. As a result, private sector performance of such functions may differ from socially optimal
levels and there may be problems of equity. Government interventions in several areas are thus economically justified.

5.21 Economies of scale (and scope) can be realized in market research, demand promotion, and, to a more limited extent, in seed storage and transport. This condition could lead to barriers to entry or competitive disadvantages for small-scale enterprises and hence the possible concentration of the industry. This condition may also lead private firms to refrain from serving relatively small or isolated market areas. The promotion of seed demand features potential externalities since widespread farmer up-take of improved commercial seeds may generate social benefits of greater magnitude than the private benefits obtained by individual farmers and the added profits obtained by seed distributors. The spin-off effects on local services and agro-industries will not be considered when a private firm considers its potential returns from promotional activities.

Because the quality of seed is multidimensional and because most quality attributes cannot be easily observed or measured prior to actual planting, there is the potential for seed promoters and distributors to profit, at least in the short-term, by misrepresenting the quality attributes of their seed. The result of such private actions may be unnecessary costs and may result in reduced yields for farmers and an overall reduction in confidence in the value of commercially-supplied seed.

5.22 A survey of seed supply systems indicates that the private sector plays a virtually exclusive role in seed marketing and distribution within advanced market economies. In contrast, in most developing countries, seed marketing and distribution features a mixture of public and private sector participation. For self-pollinated staple food crops, public seed corporations continue to play major roles in seed storage and wholesaling and in seed promotion in many countries, although little if any market research is undertaken for such crops by the public sector. In some countries, public institutions also supply such seeds directly to farmers, either through credit agencies or particular projects. This seed is usually subsidized, although in many cases such subsidies are unnecessary to stimulate use of truly superior seed. Small private firms and cooperatives are also active in the distribution of such seeds. Their ability to compete with subsidized public seed stems from their willingness to earn low margins, their provision of additional services, and the uneven or low quality of seeds supplied by some public seed companies. Once public seed companies are required to operate on the same competitive terms as private or cooperative enterprises, it is expected that the market shares of the public enterprises will decline.
5.23 The distribution of hybrid and horticultural seeds also features a mix of public and private sector activities in most developing countries, although the private sector frequently accounts for dominant market shares. Continued direct public sector involvement in seed distribution for such crops even after the private sector has developed has frequently stemmed from a strategy to cross-subsidize public company losses from distributing high volume/low value self-pollinated seeds. Such public sector involvement in high-value seed markets reduces demand for private seed. As long as competition within the private sector is maintained, such a direct public sector role is unnecessary, particularly in seed industries at intermediate or advanced stages.

5.24 Although the private (and cooperative) sector will widely participate in seed marketing given the appropriate incentives, the inherent properties of seed marketing and distribution still justify public sector interventions in a range of activities. In the early stages of seed system development there is likely to be limited information about seed demand. The government, through its existing set of agricultural and service institutions, will likely be better positioned than any private firm to collect and process information regarding potential demand. At these stages, the government can also play a major role in promoting demand for improved varieties, through the work of its extension agents and through other media. While direct government participation in seed distribution through individual projects may serve to quickly spread new varieties, such institutional arrangements are not sustainable. Built into such projects should be provisions to transfer seed distribution functions to private traders, local cooperatives, or other non-governmental organizations not dependant upon project funding.

5.25 At intermediate and advanced stages of seed system development, public organizations should not be directly engaged in seed distribution. However, important supervisory, regulatory, and service functions should be undertaken by the government which will improve the efficiency of private sector distribution activities. These include: 1) the testing and certification of seed for quality, 2) the publication of comparative variety quality tests, 3) the passage and enforcement of truth-in-advertising regulations, 4) the holding or financing of limited stocks of commercial seed to counter seed shortages following a drought or other adverse natural event, and 5) the collection, processing, and distribution of information pertaining to commercial seed demand. Such measures promote competition, counter 'moral hazard' problems, and/or provide a public service for which there is little or no scope for direct profit. For equity reasons or in pursuit of objectives related to land settlement,
security, etc., governments may also subsidize the distribution of seeds in relatively remote or sparsely populated areas.

5.26 There is no ideal institutional structure for a seed system. The most efficient mix of public and private activities varies among countries, types of crops, and stages of seed system development. Both the public and private sectors have important roles, yet there are substantial limitations on what each can do separately. Any process of seed system privatization must therefore be selective and must proceed with a recognition of what will be the required role of the public sector during this process as well as once private seed development, production, and distribution activities are well established. Selectivity in privatization moves is especially important during the early stages of seed system development when the immediate supply capacity of the private and other non-government sector may be quite limited.

5.27 Seed systems based exclusively on one type of institutional structure can not meet the diverse crop and variety needs of different seed users. This applies to both the public and private sectors. Both governments and donor agencies need to consider the potential contributions of many different types of seed enterprises and of different seed sub-system organizational models. Even where privatization is adopted as a central strategy to improve seed system performance, it must be recognized that the 'private sector' consists of many different types of entities each with different objectives, capabilities, and limitations. In promoting seed system development, a legal and economic environment should be created to allow a broad range of institutional arrangements to develop. Policies and programs should be designed which induce investments in or by 1) informal, village-level seed production and exchange operations, 2) small-to-medium-scale private local companies, 3) large local, foreign, or joint venture companies, and 4) seed associations and cooperatives.

5.28 There are a wide range of potential program, project, and policy-related activities which donor agencies could undertake to promote seed system development in developing countries and to achieve a more efficient balance of public and private roles in this process. Examples of such interventions include the following:
1) assisting in the establishment of national seed development policies which indicate the ground rules for private and public sector seed activities,

2) stimulating increased R&D activity for basic research as well as varietal development, testing, and maintenance,

3) promoting improved linkages between R&D, seed, and extension agencies,

4) strengthening institutions providing training for seed technicians,

5) strengthening official systems for seed quality control, quarantine, and certification,

6) supporting pilot projects seeking to strengthen informal, village-level seed operations,

7) supporting pilot projects seeking to encourage the formation of private seed companies for horticultural and other specialty crops,

8) providing a forum for improved contacts between public research institutions and private seed companies (both at national and international levels) to examine ways of better sharing technologies and for seed companies to better articulate their varietal requirements,

9) providing foreign exchange for the import of seed processing equipment,

10) supporting the restructuring of public seed corporations and the retraining of their personnel,

11) assisting public seed corporations in designing and implementing outgrower schemes for commercial seed production, and

12) encouraging policy changes which will reduce or eliminate barriers faced by private firms in gaining access to public sector (and foreign) varieties and germplasm and which will phase out and eventually eliminate price subsidies on public sector seed and the tying of credit to the purchase of only public sector seed.

5.29 Donor support for developing country seed systems must be more closely linked to on-going or planned support programs for other agricultural services, especially agricultural research and extension. The effectiveness of support programs in one service area may be constrained by the lack of improvement in the other service areas. The effective privatization of components of seed supply systems may require increased cooperation between public research and extension agencies and private seed companies.

5.30 An important area for further research is to examine the performance of private seed companies and to discern the apparent impact of the privatization process on such variables as overall investments in plant breeding, the levels of investments and staffing in public research, the directions
(eg. crop specialization and characteristics) of plant breeding work, the quantity and quality of seeds produced, competition in seed markets, seed prices, and effective access to improved seeds by smallholder producers. The rapidity in which the private sector emerges to effectively supplement, compete with, or replace public research and seed production should be examined in countries whose seed systems are at different stages of development. Such efficiency and equity issues have an important bearing on the proper design, timing, and phasing of any program of privatization in developing country seed systems.
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The United States is the leading agricultural economy in the world, being among the world leaders in the production of corn, wheat, soybeans, cotton, tobacco, fruit and vegetables, and livestock products. Although agriculture accounts for only 2% of national GDP and less than 3% of total employment, the sector plays a major role as a supplier of food, feed, and raw materials and an important role in U.S. foreign trade. Agriculture is one area where the U.S. has long maintained an external trade surplus.

Of a total land area of 917 million hectares, some 184 million ha. is considered cropland. Of this, some 116 million ha. (eg. 63%) was actually in production in 1987, the remainder being in fallow or reserve. Among crops, grains are the leading crop species, accounting for some 61% of the planted area. The largest plantings are for wheat (24% of planted area) corn (21%), and oats (6%). Among other types of crops, soybeans occupy the largest area, accounting for 21% of the total cropped area. Fodder crops for the livestock industry cover another 10% of the total planted area. Considerably smaller areas are planted under cotton (3.6%), fruit and vegetables (2.6%), pulses (0.7%), and a range of industrial crops (eg. sugar beet, tobacco, peanuts, flax).

The commercial seed industry in the U.S. is by far the largest in the world and the most advanced in a number of technical areas. While the public sector has long played a very important role in the introduction and development of improved varieties of major crops, seed production and distribution has been undertaken virtually exclusively by the private sector (including farmers) for much of the latter part of this century.

Seed Demand

The United States is the largest producer and consumer of commercial seeds in the world. In the late 1980’s, the agricultural sector and other consumers (eg. gardeners) utilized seed valued at more than $4 billion, with commercial seed sales accounted for about three-fourths of this total. Because of their large planted area and their relatively high seeding rates, wheat, soybean, and oats require the largest volumes of seed, followed by corn and barley. The volume of seed consumption is comparatively much lower for other crops, including rice, sorghum, cotton, fodder crops, and vegetables.

However, when it comes to the value of commercial seed sales an entirely different pattern emerges. Commercial seed sales for corn are by far the largest component of the market. With a value exceeding $1 billion, such sales account for about one-third of total commercial seed sales in the country. Corn seed sales are dominated by hybrid varieties which have contributed to significant yield increases. Hybrid corn seeds have a higher unit value and have generated high profit margins for breeders. Next in importance in commercial sales are seeds for turf crops (eg. grass for residential areas, parks, and golf courses), fodder crops, and vegetables. While the volume of such seeds planted is small relative to most grains and soybeans, the unit values for such seeds are very high. This is especially the case for certain hybrids or varieties of vegetables. Total commercial seed sales for each of these crop categories

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1 This case study is based upon Butler and Marion (1985), James (1990), Neumeyer (1991) and discussions with industry sources.
approaches or exceeds $500 million. Among other crops, only soybean seeds have a commercial sales value exceeding $200 million.

In addition to large differences in unit values among seeds for different crops, the other major factor accounting for the concentration of commercial seed sales earnings among only a few crop categories is wide differences in the proportion of seed obtained from commercial sources versus being farmer saved. In the cases of wheat, oats, and rye, it is estimated that less than 25% of the seed planted is obtained from commercial sources. Approximately one-half of the volume of seed used for soybean, peanut, and barley production is farmer-saved. In contrast, virtually 100% of the seeds planted for corn, vegetables and turf crops are commercially supplied. Such patterns indicate that even in a technically and commercially advanced seed system, a large proportion of seeds used for self-pollinated plant varieties will be farmer produced and conserved.

Structure of the Sector

The structure of the formal seed sector in the United States is unique in that while there is a mix of public and private sector activities in varietal development work, virtually all seed production, quality control, and distribution activities are undertaken by private companies, large and small. The vertical organization of the seed sector is depicted in Figure 1 below.

Within the public sector, important roles have been played by the U.S. Department of Agriculture (USDA), the State Agricultural Experiment Stations, and the Land-Grant Universities. Both historically and at present, these institutions have played a major role in collecting germplasm, in basic research, and in varietal development. Such organizations have been responsible for sourcing much of the germplasm pool upon which U.S. agriculture is based. Their development of new varieties and their wide distribution of these varieties to farmers and to firms has had an important impact on growth of agriculture and on the development of the seed industry. Research at the federal and state levels has covered a wide range of crops with cereals, vegetables, oilseeds, grasses, and legumes receiving major attention. For several crops, a large proportion of the current planted area is under varieties developed by public sector institutions. For example, more than 50% of wheat seed, 90% of barley seed, 95% or rice seed, 50% of soybean seed, and 80% of dry bean seed planted is of public varieties.

Over the past decade, public investment in plant breeding work has declined as some universities and USDA field stations have dropped their varietal development efforts or switched to basic research.

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2 Plant agriculture in the U.S. is a result of a massive importation and selection of genetic materials from around the world. Until the Department of Agriculture was created in 1862, the task of collecting germplasm was undertaken by US Treasury Consuls and officers of the US Navy. In the 20th Century, the USDA and the Land-Grant Universities have played the leading role in germplasm collection and selection.
Between 1985 and 1989, there was a decline of nearly 20% in the number of full-time plant breeders and geneticists employed in public programs (James (1990). With a reduction in efforts in applied plant breeding, the number of new varieties released by the public sector has been declining. As a result, privately-bred varieties are increasing their market shares.

Figure 1: Vertical Organization of the US Seed Sector

Within the private sector there are a wide range of different entities. One set of firms, so-called primary tier firms, are large in size and feature integrated R&D, seed production, and distribution operations. Many of these firms have multinational and multisectoral interests and market their seeds over large geographical areas. The secondary tier firms are engaged in seed multiplication, processing, and distribution, but do not have research programs of their own. Many such firms are species specific or

3 During the 19th Century the development of private seed enterprises was quite limited. The private seed trade focused on the market garden sector rather than the agricultural sector. Only with the development of new varieties by the universities and other public sector research institutions, did many small, local market oriented seed multipliers/distributors develop. The real flowering of private seed enterprises came only in the 1920's with the development of hybrid corn seed and the opportunity for product differentiation.
oriented to small local or regional markets. Some of them license the varieties of breeders in order to have their own proprietary products; others simply offer public varieties. A third type of private firm is a foundation seed company. These companies develop new varieties and supply parent materials to other breeders. Some of these companies started by drawing upon freely distributed public materials. There are also many companies which perform seed processing, packaging, and distribution functions. Some biotechnology companies are engaged in developing and selling new engineered plants or techniques only. Individual certified seed growers multiply and distribute public varieties of open-pollinated crops. Over time, the industry has become increasingly concentrated due to mergers and withdrawals and the role of non-integrated companies has declined.

Within the private sector, plant breeding research has been heavily concentrated in (hybrid) maize, followed at a distance by soybeans and horticultural crops. Substantially less research has been devoted to other cereals, fodder crops, and industrial crops. Such patterns reflect differential market sizes, the scope for appropriating research benefits, and the relative strengths and weaknesses of public research activities. Private research has been supported by public policies and programs, including the enforcement of Plant Breeders’ Rights, tax rebates on research investments, basic research programs, and the training of scientists.

Seed production is carried out within seed enterprises, by contract farmers, or by certified growers. The latter are most important for crops in which public varieties are dominant and thus there is little scope for product and price differentiation. Hence, few of the larger firms have played an active role in the multiplication and distribution of rice seed. Seed processing and conditioning is done either by the seed multiplication/distribution firms or by specialized processors operating at a local level. The marketing and distribution of seeds varies by crop and by firm, with sales conducted either through distributor agents, agricultural processors, or farmer-distributors. Although cooperatives play some role in seed distribution, their importance is far less significant than in the seed sectors of most Western European countries. Competition in the U.S. seed industry is generally very strong, although in some specific crop lines (eg. hybrid maize, cotton, soybean) a half-dozen firms account for a majority of varieties sold.

While both the federal and state governments have a mandate to regulate seed quality, non-government organizations are primarily responsible for inspecting seeds and enforcing quality standards. Such quality control is done under the auspices of state-based Crop Improvement Associations, whose membership consists of individual seed growers and seed companies.

In conclusion, in the United States all commercial seed production and trade rests in the hands of the private sector. Within this sector, a considerable degree of specialization has occurred, partly due to the country’s agro-ecological diversity, but also due to competitive pressures. Both historically and at present, this private investment and activity has been supported by public research and other public support measures. Public varieties are still dominant for several important crops, although this will change as a result of the recent and expected future decline in public research. This decline in public research may result in a reduction in new varietal development for self-pollinated crops. Even with the protection offered by plant breeders’ rights, relatively limited investments by the private sector have been directed toward plant breeding for such crops. Even in an advanced seed system such as that in the United States, the large majority of seeds planted for several major self-pollinated crops is farmer-saved.

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4 For example, data compiled by James (1990) indicate that in 1989 there were over 250 full-time plant breeders/geneticists working on maize breeding within the private sector, compared with between 15 and 40 such scientists working on the breeding for alfalfa, wheat, cotton, sorghum, and sugar beets.
Case Study # 2: The Changing Public/Private Mix in The Indian Seed System

Agriculture is the mainstay of India’s economy, employing some 70% of its 833 million people. Growth in agriculture has averaged 2.4% per year over the past two decades, slightly ahead of the population growth rate of 2.2%. While agriculture’s share of GDP has been declining, it was still 30% in 1989. Of the 3.29 million square kilometer land area, about half is cultivable and 16% irrigated. Crop production in India is quite diversified and occurs under many different agro-ecological conditions. The largest planted areas are for rice (41.9 million ha.), wheat (24.1 million ha.), pulses (23.3 million ha.) sorghum (14.9 million ha.), millet (12.1 million ha.), groundnuts (8.4 million ha.), and cotton (7.3 million ha.). There are also significant plantings of vegetables, and sugarcane.

Seed Demand and the Structure of the Sector

The main sources of seed for Indian farmers are their own retained seed and trade with neighboring farmers. As indicated in Table 1 below, less than 10% of the planted seeds for major grains, pulses, and oilseed crops was supplied by the commercial or formal seed sector in the mid-1980’s. Commercial seed sales do form a much larger proportion of total seed use for vegetables and cotton since such seeds are relatively difficult for farmers to produce and save. However, data on the seed requirements and commercial seed sales for such crops are not available.

Table 1: India Seed Requirement and Source of Supply (1985)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Total Seed Planted (1000 Tons)</th>
<th>Farmer-Saved or Local Supply (%)</th>
<th>Commercial Supply (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>2088</td>
<td>92</td>
<td>8</td>
</tr>
<tr>
<td>Paddy Rice</td>
<td>1025</td>
<td>87</td>
<td>13</td>
</tr>
<tr>
<td>Sorghum</td>
<td>992</td>
<td>97</td>
<td>3</td>
</tr>
<tr>
<td>Pulses</td>
<td>677</td>
<td>97</td>
<td>3</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>635</td>
<td>94</td>
<td>6</td>
</tr>
<tr>
<td>Maize</td>
<td>150</td>
<td>91</td>
<td>9</td>
</tr>
<tr>
<td>Pearl Millet</td>
<td>110</td>
<td>86</td>
<td>14</td>
</tr>
</tbody>
</table>

Source: Based on Pray (1990), Table 9.

The total value of commercial seeds in India is estimated at Rs. 7 to 8 billion in 1990 (eg. $389 - $444 million), ranking India among the ten largest commercial seed markets in the world. Although the volume of commercially sold seed remains small compared with overall seed use in India, such commercial volumes are still quite considerable when compared with other countries which have relatively large commercial seed markets. For example, the volume of seeds for major grains and pulses sold

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1 This case study is based on Pray (1990), Pray and Ribeiro (1990), Pray et al. (1989), and World Bank project-related documents.
commercially in India exceeds those for Canada, the United Kingdom, and Germany.

The commercial or formal seed sector is comprised of a mix of public organizations, private firms, and farmers, with significant interactions amongst them (see Figure 1).

Figure 1: India's Formal Seed Sector

![Diagram of India's Formal Seed Sector]

Source: Pray (1990)

Within the public sector component, international agricultural research centers (IARCs), such as ICRISAT, CIMMYT, and ICARDA, exchange germplasm and improved lines with India's public research institutions. The latter include some twenty-five state agricultural universities (SAUs), twenty-one All India Crop Improvement Projects, and the India Council of Agricultural Research (ICAR) which oversees these and other public programs. These public institutions undertake both basic and applied research and then produce breeder and/or foundation seed of improved varieties to supply both public and private seed companies.

The major public sector producers of certified seeds are the National Seed Corporation (NSC), created in 1963, and thirteen State Seed Corporations (SSCs), most of which were created during the 1970's. Neither the NSC nor the SSCs directly produce large volumes of seed. Instead, each relies upon large numbers of contract farmers whose production they oversee and whose seed crop they purchase. A small proportion of the seed procured by the NSC is obtained from the State Farm Corporation of India (SFCI) which operates several large seed farms. Both the NSC and the SSCs operate large, centralized seed processing plants. There is considerable duplication in the investments and activities of the NSC, SSCs, and the SFCI. The public seed corporations distribute their seeds through several channels, the most important being government-appointed dealers, state agricultural projects, and cooperatives. Government-produced seeds are typically subsidized by the national and/or state governments. The public
sector corporations lack a commercial orientation with their activities being heavily influenced by political and interest group pressures.

The private sector is comprised of a diverse mix of enterprises of varying sizes, ownership characteristics, and operational specializations. One set of firms consists of subsidiaries of multinational seed, chemical, or food companies. Most of these operations combine varietal development and testing, seed multiplication, and processing. The majority of these foreign investments have been undertaken during the past five years. Among Indian-owned firms there are about six large seed and agribusiness enterprises combining research, production, and processing, with seed turnovers exceeding Rs. 50 million. Restrictions on landholdings have led each of the major seed companies to rely predominantly upon contracted growers for seed multiplication. Another dozen or so firms are medium-scale with annual seed sales of Rs. 10-50 million. These companies have very limited research programs, focusing on multiplying and distributing publicly-bred varieties. An additional 40 to 50 smaller seed enterprises organize seed multiplication schemes and perform wholesale, storage, and transport functions. Finally, there are several thousand small local distributors who have direct contact with farmers.

There are important interactions between the public and private sectors. For example, much of the genetic material, self- and open-pollinated varieties, and inbred lines used by the private sector is obtained from the Indian public research institutions or the IARCs. For example, from a sample survey of twenty-four private seed companies, Pray et al. (1989) found that sixteen firms obtained germplasm for pearl millet from ICRISAT and six firms obtained germplasm for the same crop from Indian public universities. Nineteen of the sampled firms obtained pearl millet breeder seed from ICRISAT, while ten obtained sorghum breeder seed from the same source. Only the MNC subsidiaries obtain much of their germplasm from private sources (eg. their subsidiaries in other countries), although such material may also have originally derived from public research. In addition, most of the scientists presently employed by the private companies in India received their training from and frequently worked at the public universities and research stations or at ICRISAT. Some private firms have been recognized by the Indian Government as R&D Centers. This allows such firms to write off 100% of their capital investment costs and to import scientific equipment on a duty free basis.

The private sector has focused its plant breeding work on sorghum, pearl millet, maize, cotton, sunflower, and selected oilseed crops and vegetables (Pray and Rubiero (1989). For each of these crops there is scope for successful hybridization, thus providing firms with some degree of 'natural protection' against competition as well as higher margins on their sales (Ibid.). The former is important since the plant varieties listed above are not legally protected in India. For this range of crops, the applied research expenditures for the public and private sectors have reached similar levels in recent years. However, the majority of privately-bred hybrids are based on germplasm or other materials obtained from public sources.

In a survey of companies active in millet and sorghum research and seed production, Pray et al. (1989) found the average seed sales to be Rs 34 million for those firms engaged in R&D versus an average of only Rs 2.6 million for non-R&D firms.

There is little evidence that the recent expansion of private plant breeding has undermined public research efforts. While private firms have hired scientists from the public institutions, there are still only one hundred PhD or Msc scientists working for private seed companies compared with over 10,000 at the public institutions.
In terms of the volume of certified seed production, public corporations accounted for a dominant share during the mid-1980's, producing almost all of the certified seed for self-pollinated crops. In 1985, public sector seed production amounted to 240,000 metric tons out of an estimated total commercial market of 420,000 metric tons. At the time, about 60% of public sector seed production consisted of rice and wheat seed. Even for sorghum and pearl millet, crops in which the private sector has invested heavily, the public sector still accounted for a large majority of seed production.

Although data are not presently available, it is estimated that the private sector’s share of commercial seed volumes has increased to reach over 60% of the total in 1990. With the private sector concentrating on hybrid varieties and with the perceived (and sometimes actual) higher quality of many of the private varieties, the estimated share of the private sector in the value of commercial seed sales is higher, perhaps reaching 70%. In addition to developing their own hybrid and other varieties, private firms have been active in multiplying new public varieties and hybrids of coarse grains.

Table 2 summarizes the mix of public and private roles in India's seed sector. It indicates the overlap of undertakings, particularly after the stage of varietal development. A dominant private sector role is found only in the distribution of vegetable seeds.

The Historical Evolution of the Sector

Prior to 1960, the organized seed sector played a minimal role in Indian agriculture. Under the First and Second Five-Year Plans during the 1950's, State Departments of Agriculture set up small seed farms in each Community Development Block in order to multiply seed of locally improved varieties. However, there were difficulties in managing so diffuse a scheme and the quality of seed produced was little better than that saved by farmers themselves. Private companies concentrated on vegetable and flower seeds and on seedlings and planting material for crops which couldn’t be well maintained by farmers. The market for commercial seed remained very small.

The 1960's witnessed a dramatic expansion in the organized seed industry, driven by public research programs which released a series of hybrid and high-yielding varieties of major grains. In 1961, the first maize hybrids adapted to Indian conditions were released for general cultivation. Hybrid varieties of sorghum and pearl millet were released in 1964 and 1965. In subsequent years, high-yielding varieties of rice and wheat were first imported and then developed locally. In 1969, Indian scientists produced the world's first hybrid cotton. As a result of the introduction of the HYVs, there was a rapid growth in demand for commercial seeds, well beyond the capacity of existing production and distribution systems. State governments tried to expand production on their farms and to distribute seed through extension departments, but this proved inadequate. The wide scatter of small seed farms was inappropriate to the technological needs of hybrid seed production and the volumes of seed demanded for HYVs of rice and

While there is growing involvement by the private sector in plant breeding, most varietal development work in India is still conducted by the public sector. Nearly all plant breeding work on self- and open-pollinated crops is undertaken by the public sector and the vast majority of HYV and hybrid varieties of wheat, rice, maize, coarse grain, and oilseeds have derived from the central government institutes and the SAUs. Public sector institutions have also been very active developing hybrid varieties for major cereals, forage crops, and cotton. Over the past fifteen years, some 1400 varieties have been released by public sector institutions.
<table>
<thead>
<tr>
<th>Crops</th>
<th>Variety Sourcing/Development</th>
<th>Seed Production/Processing</th>
<th>Seed Marketing/Distribution</th>
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<tr>
<td>Wheat</td>
<td>NA</td>
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<tr>
<td>Rice</td>
<td>NA</td>
<td>G</td>
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<tr>
<td>Maize (hybrid)</td>
<td>P</td>
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<td>M</td>
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<tr>
<td>Potato</td>
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<td>Seedlings</td>
<td>NI</td>
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<td>M</td>
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<tr>
<td>Forage</td>
<td>NI</td>
<td>G</td>
<td>G</td>
</tr>
</tbody>
</table>

Codes:
- **G** Predominantly Government Enterprises, Agencies, and Institutes (eg. 90% or more)
- **P** Predominantly Private Enterprises, Individuals, and Institutes (eg. 90% or more)
- **M** Mixed Government and Private Involvement (eg. significant but separate roles for each)
- **C** Seed or Producer Cooperative
- **CON** Government contracting out to private firms or farmers.
- **N.I.** No information available on existing formal activity.
- **N.A.** No formal activity.
As a result, the government decided to create a central seed organization, the National Seed Corporation (NSC) in 1963. The NSC's initial mandate was 1) to produce single crosses of hybrid maize and to organize the production of maize seed through contract growing on government, cooperative, or private farms, and 2) to import HYV rice and wheat seed in bulk and to distribute such seed. With the passage of Seed Law in 1966, the NSC's responsibilities were expanded to include quality control inspection and the promotion of improved seed processing, storage, and distribution. While the Seed Law established rules for testing and certification, it did not make certification mandatory, permitting firms to sell "truthfully labelled" seed instead.

Through the mid-1960's seed output expanded rapidly with the certified seed growing area expanding from about 360 ha. in 1963 to 35,000 ha. in 1969. During this period, the NSC concentrated mostly on foundation seed production while most certified seed was produced by contract growers. Numerous private firms entered the sector, many receiving technical assistance from the Rockefeller Foundation, USAID, and/or Indian public institutions. The Rockefeller Foundation and USAID also supported the development of a local seed processing equipment industry. Several private firms benefitted from supply contracts with the NSC and the State Agriculture Departments, typically with sales made at favorable prices. While some private firms concentrated on multiplying public hybrids, others focused on supplying the rapidly expanding market for HYV rice and wheat seed which farmers could not multiply fast enough to meet demand.

The boom in seed production outpaced farmer demand for commercial seed. In the self-pollinated crops, especially rice and wheat, farmer retention and farmer to farmer transfers accounted for much of the seed used. Some of the new hybrids were inferior in grain quality to traditional types and thus lost favor among farmers. Companies which depended on hybrid corn production suffered from the success of HYV rice which replaced corn in some areas. The result was a rapid buildup of seed stocks, especially for hybrid varieties of sorghum and maize and for HYV wheat. With state governments incurring heavy losses maintaining such seed stocks, they largely withdrew from direct contracting of seed requirements with the NSC and private companies. This had a major impact on the private sector, with large numbers of firms being forced into liquidation.

Demand for hybrid and other improved commercial seed began to expand in the early 1970's, although the private sector lacked both the resources and the confidence (due to the oversupply problems in the 1960's) to meet it. In response, the NSC undertook the production of certified seed on a larger scale and diversified beyond maize seed. Between 1970 and 1974, NSC's production of certified seeds of the five main cereals went up three-fold from 9500 to 30,000 tons and more than doubled again the following year to over 70,000 tons. This expanded production was almost entirely on contracted outgrower farms which were widely scattered. The NSC faced major problems of supervising production and of quality control.

At the same time, State Departments of Agriculture sought to develop programs to expand contracted production of seeds. One of the most innovative schemes was undertaken in Uttar Pradesh by the agricultural university located in Pantnagar. This scheme, called the Tarai Development Corporation, received technical and financial support from the World Bank. The scheme involved university and outgrower production of foundation and certified wheat, rice, maize, and soybean seed. Production and distribution were undertaken throughout northern and eastern India of varieties developed by the
university, the IARCs, and other public institutions. The corporation developed its own network of dealers in several states. TDC was developed as a joint venture between the university (30%), the NSC (20%), participating farmers (30%) and other agencies.

With the success of the TDC and with pressures to enhance food security, the government launched a National Seed Program during the mid-1970's. Under the program, State Seed Corporations (SSCs) were to be created in regions which possessed a comparative advantage for producing particular crops. Each crop was to be produced by more than one SSC to ensure competition and safeguard production. Certified seed was to be produced by contract growers in relatively compact areas, in contrast to the scattered production overseen by the NSC. As part of the program, the NSC would gradually phase out of certified seed production of major grains and concentrate on foundation seed production for such crops and vegetable seed production. The NSC was assigned the role of coordinating inter-state trade in seeds. Each of the SSCs were to construct or enlarge existing processing plants and each state was to develop its own seed certification system. The National Seed Program and the development of the SSCs were partly funded by the World Bank. After an extended delay in project start-up, the SSCs began producing seeds in the late 1970's.

The private sector was largely neglected by the government during the 1970's and featured little in the National Seed Program. The passage of the Monopolies and Restrictive Trade Practices Act of 1969 prevented Indian companies with assets exceeding Rs. 1 billion and companies with more than 40% foreign ownership from selling seeds in India. As a result, only one foreign company, Pioneer, invested in the industry during the 1970's, holding a minority interest in a company. Technical support for the private sector was also reduced as both the Rockefeller Foundation and USAID ended their programs in India in 1972. Stringent controls were placed on the import and export of seeds. Nevertheless, the private sector expanded its share of the market for hybrid varieties, having an estimated 40% share for maize, 90% for sorghum, 70% for pearl millet, and over 90% for vegetables during the mid-1970's. Most companies multiplied and distributed public hybrids, although a few larger companies did develop their own varieties. The restrictions against large (multinational) firms participating in the sector greatly inhibited the extent of private investment in varietal development research.

India's commercial seed industry expanded considerably during the 1980's, both in the private and public sectors. A private sector boom has occurred over the past five years, stemming in part from several policy changes. One policy change made in the early part of the decade was to allow private firms to obtain breeder seed directly from ICRISAT and other public research institutions. A 1987 change in industrial licensing policy allowed large-scale Indian companies and foreign-owned companies to participate in the seed industry. A third policy change was a major liberalization of seed imports and exports in 1988. Much of the growth in the private sector has stemmed from either foreign investments or from spin-offs from previous companies, with technical and marketing personnel branching off to start their own seed companies. One firm alone, Maharashtra Hybrids, has given birth to at least eight additional private companies since the mid-1970's. Several of the branch off companies have sold their original company's hybrid varieties under a new name, undermining the latter's appropriability of benefits from their research and product development. Private sector growth has been fastest for sorghum, pearl millet, cotton, and vegetables. For vegetables there has been a large increase in both imports and exports over the past few years.

The expansion of the private sector has taken place despite a rapid growth in government seed supply. Between 1979 and 1984, public sector production of certified seed increased from 113,302 tons to 272,019 tons. While more than doubling production, actual output has still lagged well behind the
planned production under the National Seed Program. As a result, most SSCs have operated their processing facilities at well below capacity. With farmer retention of rice and wheat seed being much larger than expected, large carry-over stocks have accumulated. Research in several states has indicated that the SSCs have not played an important role in the more recent spread of HYVs of wheat and rice. Once foundation seed has been provided by the public universities, its multiplication and spread between farmers has tended to be rapid.

The above patterns, together with political pressures to pay higher prices to contract growers and to subsidize farmer consumers of seed, have contributed to significant financial losses for many SSCs. Accumulated losses for some SSCs (and the NSC as well) are in the hundreds of millions of Rupees, thus putting a strain on national and state budgets. Due to these losses and due to the growing strength of the private sector, the future viability of the NSC and some SSCs is in doubt. The NSC is presently seeking to reorient its role to that of producing foundation seed (and seed for specialized crops), providing training, and regulating aspects of the seed industry. Some SSCs have sought to compensate for their losses from producing and selling rice and wheat seed by enlarging their operations for hybrids, thus coming into competition with the private sector. The NSC and SSCs have frequently competed with one another with overlaps in production within individual states and with some SSCs also engaging in inter-state seed trade. The lack of commercial accountability by the NSC and SSCs and the considerable duplication of their investments has led to near anarchy on the public sector side of the seed industry.

**Conclusion**

In conclusion, the Indian experience illustrates the importance of the public sector (especially in research) in the development of the private sector. Public plant breeding breakthroughs in the 1960's created the demand as well as the products for the private commercial seed industry. In the absence of such breakthroughs, a private seed industry would have started much later and developed more slowly. Nevertheless, the case also illustrates the handicaps which governments can place on private sector development, in this case deriving from licensing, trade, and landholding policies.

Consistent with our theoretical discussion in Section 3, private firms in India have focused their varietal development work and their seed production and distribution on hybrid varieties of commercial and food crops for which the scope for appropriability of part of the benefits is greatest. Neither private firms nor the SSCs can compete with farmers in multiplying and distributing seeds of self-pollinated rice and wheat varieties.

The private seed industry has expanded in a very dynamic fashion over the past decade with many new investments and spin-offs from previous companies. This expansion has occurred despite a simultaneous growth in public sector seed production and despite the fact that the on-going National Seed Program has, until recently, directed extremely few resources to the private sector. The private sector has drawn technical resources from the public sector and begun to meet the large and growing demand for improved seed of major and non-traditional crops. With presently low usage of improved seeds for many crops, the scope for expanded market development in India is vast.

The Indian case also illustrates the very high costs associated with major public sector

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5 The National Seeds III Project, which became effective in 1989, has a credit component of $30 million with a large proportion of this credit going to finance private sector seed investments.
participation in certified seed production and distribution when such activities are not commercially oriented and dictated by political considerations. The future direction of public sector participation in seed production should be to focus on plant breeding and foundation seed production for self-pollinated crops and on providing technical and other support to local-level farmer seed multiplication and distribution schemes for these and other crops. The SSCs and NSC should be instructed to phase out their own certified seed production operations, while strengthening their capacity to support and regulate the private sector. This will entail a rationalization of a large part of their infrastructure and staff.
Case Study #3: Public, Private, and Cooperative Sectors in The Mexican Seed System

As a result of expansion in the petroleum industry and in manufacturing, the share of agriculture in Mexico’s GDP has declined from 15% in 1960 to 11% in 1970 to 8% in 1988. Nevertheless, agriculture remains a very important sector of the Mexican economy, providing the bulk of the country’s expanding food requirements, providing raw materials to manufacturers, and providing employment for about one-third of the active labor force. Approximately two-thirds of agricultural GDP is accounted for by crops. Maize is the single most important crop, being the staple food in the local diet and covering about one-half of the planted area. Other major crops in terms of planted area, importance in diet, and value include sorghum, dry beans, wheat, vegetables, forage crops, oilseeds (soybean, safflower, and sesame) and cotton.

Mexican agriculture can be divided into several segments, including a large farm commercial sub-sector and semi-commercial and subsistence smallholder components. Some 30% of agricultural land is irrigated, yet production in irrigated areas accounts for nearly one-half of the value of production. While most production of maize and dry beans is undertaken by smallholders under rainfed conditions (some with intercropping), most wheat, vegetable, oilseed, cotton, and forage crop production is done under irrigation on larger farms. The technologies of production differ significantly between irrigated and rainfed areas with the former featuring more intensive use of fertilizer, machinery, and improved seed. It is estimated that about 90% of the seeds planted in irrigated areas are improved seeds obtained from commercial sources, compared with only 10-15% in the rainfed areas.

Seed Demand and the Structure of the Seed Industry

The estimated value of commercial seed sales in Mexico during the late 1980s was $275 million, ranking the market among the ten largest in the world. While maize and dry beans are the leading food crops, some three-quarters of the seed used for such crops is farmer saved. Most maize and dry bean production is undertaken by smallholder farmers in rainfed areas where newly-developed varieties have generally not had significant advantages over traditional cultivars. In contrast, for such crops as sorghum, cotton, vegetables, and fodder crops, the planted seeds are obtained almost entirely from commercial sources. The highest values for commercial seed sales are for sorghum, vegetables, and fodder crops. The vegetable seed sub-sector has been especially dynamic, supporting Mexico’s expanding export trade in fresh and processed vegetables.

Mexico’s seed industry is one of the oldest and most advanced among developing countries, rivaled only by India, Argentina, and Brazil. The seed industry has a very mixed structure with major involvement by both the public and private sectors. Within the public sector, crop variety research and the production of breeder seed is undertaken primarily by INIFAP (the National Crop, Livestock, and Forestry Research Institute). INIFAP develops its own improved varieties of maize, beans, sorghum, cotton, rice, wheat, and soybeans, drawing from its own genebank and from genetic material provided by international agricultural research centers. Of the latter, CIMMYT is most important as it is based on

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1 This case study is based on Goodman (1982), Peterson et al. (1989), Echeverria (1990), and World Bank documents.
Mexico. CIMMYT conducts much of its research (on maize and wheat) on INIFAP experiment stations and the two organizations jointly undertake adaptive tests.\footnote{INIFAP employs more than 1000 researchers, about one-third of which at the PhD. or Msc. levels. Other public sector organizations doing plant breeding research include the Colegio de Posgraduados and the Technological Institute of Monterrey for which plant breeding is derived from basic research activities.}

Varieties developed by INIFAP are provided to Productora Nacional de Semillas (PRONASE) a parastatal seed enterprise, and to local producer organizations. PRONASE was established under the Seed Production, Certification, and Marketing Act of 1960 and inherited substantial holdings of land, equipment, and staff for seed production from its predecessor, the Comision Nacional de Maiz. The Seed Law gave PRONASE a virtual monopoly on INIFAP materials. While PRONASE does undertake some seed multiplication on its own farms, the bulk of its production of certified seed is undertaken by contract farmers, of which there were 5600 in 1985. PRONASE has its own processing facilities throughout the country. A large proportion of PRONASE's seed sales (nearly 40% in recent years) have been directed to or through the National Rural Credit Bank (BANRURAL), providing the parastatal with a relatively secure market outlet. Unlike national seed companies in many other countries, PRONASE has been active in a wide range of seeds, although nearly 90% of the company's sales has been of seeds of major staple crops (e.g. maize, dry beans, rice, and wheat). PRONASE's activities are now limited to the latter four crops.

Between 1960 and the late 1970's, PRONASE became one of the largest parastatal seed companies in the world. Its virtual monopoly access to INIFAP-developed varieties, government operating subsidies, and restrictions placed on foreign investment guaranteed the company a dominant share of the local market. Over this period, the company's sales increased from only 5000 tons to over 100,000 tons. By 1978, however, PRONASE was financially bankrupt, requiring a government bailout and a large subsidy increase. Over the next several years, PRONASE's certified seed production expanded substantially as part of the government's rural development program (Sistema Alimenticio Mexicano) which heavily subsidized the use of purchased seed. PRONASE's production increased from 106,000 tons in 1979 to 362,000 tons in 1982. By 1983, when SAM was phased out, PRONASE's production fell to 165,000 tons. Seed sales also widely fluctuated, although much of the expanded production was put into storage at high expense. Since 1984, there has been an improvement in PRONASE's financial position with profits recorded in each year and with a substantial decline and then total elimination of the federal subsidy.

The private sector consists of two major segments: 1) private enterprises and 2) farmer associations. There are approximately forty private seed enterprises, 75% of which are Mexican-owned, the others being joint ventures or affiliates of multinational corporations. Major MNCs active in Mexico for seed (as well as related inputs) include Pioneer, Dekalb, Upjohn, Ciba Geigy, Cargill, and Sandoz. Most of their investments occurred during the 1980's following changes in Mexican law permitting more than 50% foreign ownership in industrial and agricultural firms.

Only seven of the active private seed companies are involved in any type of varietal development work. Most of this work is testing varieties imported from the US, Latin America, and elsewhere in screening trials in Mexico.\footnote{Nevertheless, Echeverria (1988) indicates that the private firms invest considerably more money per scientist than does the INIFAP.} While CIMMYT is prohibited from distributing germplasm directly to
private companies in Mexico, firms have used CIMMYT germplasm which has been exported to the U.S. and re-imported into Mexico. Local private companies do little research of their own. Their limited access to germplasm has placed them at a distinct competitive disadvantage vis-a-vis both PRONASE and multinational corporations active in Mexico. This pattern lies in strong contrast to that in India where there has been extensive interaction between public research and local private seed companies. Only with a new seed law passed in 1991 have local firms been given the right and opportunity to obtain germplasm or finished varieties from INIFAP.

Table 1 depicts the mix of public, private, and cooperative interests in the Mexican seed sector. Within the private sector, most seed multiplication is undertaken by contracted farmers, supervised by the companies. Seed distribution is undertaken through private distributors, farmer organizations, and BANRURAL. The importance of the BANRURAL channel differs significantly between firms with some private firms channeling 30% or more of their sales to or through the public credit organization. The private sector has focused its research and production activities on hybrids, especially of maize and sorghum. The private sector has also focused its attention on varieties suitable for large-farm commercial growers operating under irrigated conditions or in the mid-altitude northern and western areas. Within the set of varieties sold by the private sector, nearly one-half are imported with the other half being of national origin. Several of the multinational companies active in Mexico's seed industry have focused their activities on the northern state of Tamaulipas on the U.S. border where hybrid seeds developed in Texas are suitable.

The other important component of the private sector consists of farmer associations and ejido groups. Some farmer organizations have affiliations with particular agro-industries; others are area-based. Some are comprised of smallholder farmers; others are comprised of large-scale commercial farmers. These organizations generally receive breeder or foundation seed from INIFAP, although some import finished seed. They select from among their members the farmers who will multiply seed. These farmers are under contract with the organization, although the contractual requirements and the intensity of supervision are generally far less stringent than in the case of private companies. Primarily open-pollinated varieties are multiplied. Most seeds are sold directly to members of the organization as part of a package of membership services.

While private sector (including farmer associations) seed production and sales have expanded considerably over the past fifteen years, PRONASE still accounts for a large share of the volume of certified seed production. In 1986, PRONASE's share of such production for major crops was 38%, down from 53% over the 1980-82 period. Because of the concentration of PRONASE's sales in relatively low value foodgrains, its share of commercial sales earnings has been substantially less. In 1987, PRONASE's share of commercial sales value was only 23.6%, compared with 66.9% for private firms, and 9.5% for farmer associations.

Private firms have a dominant share of the markets for sorghum, fodder crop, and vegetable seeds and are also important for cotton, soybean, and (hybrid) maize seeds. For each of these there is scope for hybridization and unit values are relatively high. In contrast, private firms have relatively little interest in seeds for rice, wheat, dry beans, and open-pollinated maize, these being areas where there is currently little scope for appropriating the benefits from investment. The seed market shares for the private sector for such crops is less than 20%. PRONASE has a dominant position in the markets for (open-pollinated) maize and dry beans and shares with farmer associations the markets for wheat and rice seeds.
The market share of PRONASE is expected to decline as a result of the newly permitted access of local private firms to INIFAP-developed varieties, changes in the credit system which permit borrowers from BANRURAL to purchase seeds other than those supplied by PRONASE, and competition within the private sector which should push firms into market segments presently handled by the state corporation. PRONASE’s prospects are uncertain. With no federal subsidies, the organization’s comparative advantage lies only in relatively low value self- and open-pollinated varieties of basic grains in which private seed enterprises have shown little interest. A logical division of labor between the private and public sectors would be for the private sector to continue its focus on hybrids and on the higher potential areas and for PRONASE to focus on improved seed for rainfed areas. PRONASE could focus on foundation seed production for self- and open-pollinated varieties and on supporting farmer association production of certified seed.

Adjustments will be necessary. During the 1970’s, nearly one-half of the maize varieties sold by PRONASE were for irrigated areas and PRONASE has been not successful in spreading improved maize cultivars to most of the area of rainfed production. While there are presently large gaps in the coverage of privately produced and distributed seeds, competition amongst private firms will likely lead them to increasingly serve at least the higher potential rainfed areas.
Table 1: Institutional Mix in Mexico’s Seed Sector

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<tr>
<th>Crops</th>
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</table>
Case Study 4: Public, Private, and Cooperative Roles in the Zimbabwe Seed System

While agriculture's contribution to national GDP is relatively small (11% in 1989), the sector's contribution to the Zimbabwean economy is significant. For example, 1988 agriculture accounted for about 70% of formal employment and 40% of total merchandise exports and provided about half of the country's manufacturing sector with raw materials. The performance of the agricultural sector has been mixed since independence (1979). Between 1980 and 1988, the growth rate of agricultural output in constant prices was 2.2%, well below the estimated population growth of over 3.0% during the same period (World Bank 1991). During this period, the real value of agricultural exports has remained stagnant. Nevertheless, in terms of growth, exports, and productivity, Zimbabwean agriculture has performed better than the agricultural sectors in most of sub-Saharan Africa.

At independence, Zimbabwe inherited a highly dualistic agricultural and land tenure system with a relatively small number of corporate and other large-scale farms occupying much of the high potential areas and with nearly a million smallholder families relegated to lower potential areas. As a result of land sales and resettlement schemes, there has been some transfer of land from the large-farm to the smallholder sub-sectors. Still, land distribution remains highly skewed and the large and small farm sub-sectors continue to operate at different levels of technology, commercialization, access to services etc.

The most important crop in Zimbabwe is maize, this being the staple food for much of the rural population. Maize occupies 30% of the cropped area in the large farm sub-sector and 50% in the communal areas. Other major food or commercial crops include groundnuts, sorghum, cotton, tobacco, soybean, wheat, fodder crops, and vegetables.

Zimbabwe differs from much of Africa in that it features a relatively well functioning commercial seed industry. Also unique in the African context (with the exception of Kenya) is the fact that Zimbabwe's seed sector has featured a dominant role for the private sector (including commercially-oriented cooperatives) in production and distribution. The institutional arrangements linking public research with private seed commercialization in Zimbabwe are unique in an international context.

**Commercial Seed Market**

Through to the late 1970's, the sale of improved seed was made almost entirely within the large farm sub-sector, with smallholders in the communal areas producing and retaining their own seed. Through this period, maize seed dominated the commercial market, accounting for some 80-90% of sales. Remaining commercial seed sales were for cotton and tobacco for specialized export-oriented production.

During the 1980's, the commercial seed market in Zimbabwe has expanded and undergone several changes. The most significant change has been the spread of hybrid maize to the communal areas and rapidly growing share of the smallholder sub-sector in commercial seed purchases. During the first half of the 1980's, the country experienced a rapid penetration of hybrid maize into the communal areas, increasing the volume of commercial seed sales in these areas from only 4300 tons in 1979/80 to over 20,000 tons. The high adoption rate for hybrid maize could be attributed to farmers' familiarity with the

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1 This case study is based on Friis-Hansen (1991) and the World Bank's (1991) Zimbabwe Agriculture Sector Memorandum.

2 In 1988, the large-scale commercial sector (numbering about 4600 farms) controlled 34% of the nation's agricultural area and accounted for 82% of crop sales and 40% of export earnings.
crop, the availability of varieties suitable for rainfed areas, the obvious food security benefits, and the government's campaign to increase maize cultivation in the communal areas via increased extension activities, increased credit, and providing relatively favorable prices for the crop. By the late 1980's, hybrid maize seed sales reached between 25,000 and 30,000 tons and over Z$ 40 million, three-fourths of which directed to the communal areas. The adoption of hybrid maize is almost universal in Zimbabwe and indeed there is an official ban on the sale of open-pollinated varieties. Improved varieties of cotton also almost universal, both in the communal and large farm sectors.

Commercial sales of seeds for other crops are much more limited, especially within the communal areas. Only for wheat and soybeans do domestic sales exceed Z$ 1 million. The limited development of other commercial seed markets stems either from the fact that no varieties have been developed which are appropriate for the communal areas (eg. barley and wheat) or because of problems of seed production capacity, seed pricing, seed marketing, or more general weaknesses in agricultural marketing systems (eg. sunflower, groundnut, vegetables). In the case of sunflower, hybrid seeds are four times more expensive than retained seed, yet offer no significant yield advantage. Improved sunflower seeds are seldom found in rural retail shops. For groundnuts, seed supplies have been subject to major quality control problems. In the case of soybean, most attention has been given to breeding varieties with higher oil content, yet such a quality variable is not differentially rewarded by the Grain Marketing Board, the sole processor of the crop. The vast majority of improved soybean seed is sold to large commercial farmers. Because of low yields obtained under local conditions, domestic production of many varieties of vegetables has not been economic. Major seed distribution companies have not aggressively sought to market open-pollinated varieties of sorghum in communal areas. Seed of improved varieties of cowpeas, field beans, and other legumes are not produced by the Zimbabwe seed industry. Table 1 indicates the proportion of seeds obtained from commercial vs. self-saved seeds within the smallholder communal areas for selected crops for which survey data are available.

Table 1: Source of Seed for Communal Farmers (%)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Farmer-Saved</th>
<th>Commercial Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>2.1</td>
<td>97.9</td>
</tr>
<tr>
<td>Cotton</td>
<td>3.0</td>
<td>97.0</td>
</tr>
<tr>
<td>Sunflower</td>
<td>50.4</td>
<td>49.6</td>
</tr>
<tr>
<td>Sorghum</td>
<td>56.1</td>
<td>43.9</td>
</tr>
<tr>
<td>Groundnut</td>
<td>71.5</td>
<td>28.5</td>
</tr>
<tr>
<td>Legumes</td>
<td>100.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Source: Based on Friis-Hansen (1991)

Structure of the Seed Industry

Varietal development research is undertaken both within the public and private sectors in Zimbabwe. Within the public sector, the most important actor is the Crop Breeding Institute which undertakes research and develops breeder seed for a wide range of crops, including maize, wheat, sorghum, millet, groundnuts, legumes, potatoes, soybeans, and sunflower. Each individual program is
small and the CBI's total budget in 1990 was ZS 250,000. Plant breeding or adaptive research is also undertaken by ICRISAT (for sorghum and millet) and by the University of Zimbabwe. A non-governmental organization called ENDA-Zimbabwe tests and distributes composite varieties of maize, sorghum, and millet, while special institutes, receiving both public and private funding, conduct plant breeding and other research on tobacco and cotton.

Until recently, varietal development research by the private sector has been very limited. During the 1980's, several multinational corporations did conduct demonstration trials using varieties developed elsewhere, but these were not followed up by investments in Zimbabwe. The only exception is for Pioneer which has embarked on a ten-year program of varietal development and adaption, focusing on hybrid maize. In recent years, the leading national seed producer, Seed Coop, has expanded its varietal development and testing work. The organization, in collaboration with the Crop Breeding Institute, conducts extensive trials of government-bred varieties on its own research farm. While the majority of tests are hybrid maize trials, some trials are also conducted for wheat, barley, soybeans, groundnuts, and sunflower. The cooperative has also established its own breeding programs for maize, wheat, and soybeans.

Since the 1950's, seed production has been undertaken under the framework of crop seed associations. These associations, consisting of large-scale commercial farmers, were created to oversee and certify seed production. Such seed associations were set up for various crops, including maize, tobacco, potato, and pastoral crops. While such associations closely cooperated with government research institutions during the 1950's and 1960's, beginning in 1967 such cooperation was formalized in agreements between government agricultural research stations, individual associations, and their membership. These agreements stipulated that the government would release to the associations all new varieties developed by public research stations and grant the associations exclusive rights to multiply and sell seeds of these varieties. While the plant breeders rights would be retained by the public research institutes, the associations would not have to pay royalties. Under these agreements, a production schedule would be developed annually and agreed upon by the government, the seed associations, and their members. This would ensure that the country's demand for seed was secured. In addition, the seed associations are required to produce sufficient seed to meet the demand of farmers and to maintain a buffer stock of 20%.

While the first such agreement concerned varietal release and seed production of maize, subsequent agreements were made for sunflower, wheat, barley, soybeans, groundnuts, and sorghum. These agreements have effectively created politically controlled monopolies within private hands. Although not formally built into the agreements, understandings are reached between the government, the associations, and the participating farmers providing guaranteed prices to seed producers on an annual basis.

In 1983, the Seed Maize Association merged with the Crop Seed Association to form the Seed Co-op. This organization has been the dominant producer of certified seed since then, accounting for 95% of hybrid maize seed sales. The organization is a cooperative with some 156 members who are large-scale commercial farmers. Each member is given an equal production quota based on expected sales. Members are obliged to sell their seed output to the coop at prices negotiated between the coop, its members, and the government, yet with some variations according to the timing of delivery. In the realm of quality control, there is close collaboration with the Seed Services section of the Ministry of Agriculture. Field service personnel are based at Seed Co-op's headquarters. Each inspector is responsible for a particular area, incorporating some twenty certified growers. Multiple inspections are undertaken during the
production season. All maize seed is processed on the farms of members, while for wheat and soybeans, the majority of the processing is done in a more advanced, centralized Seed Co-op processing plant. Of 1990 seed sales of nearly Z$ 50 million, 80% of the coop’s revenues were for maize seed with an additional 15% coming from wheat and soybean seeds.

There are several other commercial seed producers in Zimbabwe. One is Savanna Seed Company which is linked with Pioneer’s company in South Africa. Seed multiplication is done on contract by large-scale commercial farmers located in the vicinity of Savanna’s central grading and processing plant. Most production is of maize seed, although small quantities of other seed crops are also produced. Another company is National Tested Seed which owns two commercial farms and uses outgrowers to produce open-pollinated maize, sorghum, and sunflower seeds for the export market. Several other seed producers have major public sector interests. One of these is ARDA which operates large-scale state farms producing a wide range of crops and is the largest single user of seed in the country. In the mid-1980’s, ARDA became involved in seed production, partly as a special Seed Co-op member and partly on its own.

While groundnut seed was covered under an agreement with a private seed association, in 1983 its production was transferred to the Grain Marketing Board by a decree from the Minister of Agriculture. The GMB set up a system of out-growers, but did not provide sufficient incentives from growers to produce the short season variety Plover, released by the government in 1982 and preferred in the communal areas. In response, the organization simply processed and cleaned groundnuts purchased from communal areas and offered it for sale as seed. Quality control was insufficient and the organization mixed up different varieties. By the late 1980’s, seed of the Plover variety was still not available to communal area farmers. To counter the problem, in 1989 the responsibility for multiplying groundnut seed was transferred back to the private sector with the Seed Co-op being given exclusive rights to multiply seeds of the Plover variety.

The Cotton Marketing Board has a monopoly on seed multiplication and marketing. It has operated a system of out-growers, but with far greater effectiveness than the GMB. The Board has exercised strict control over the varieties planted and of the quality of the seed. The only major exception was in the years 1987/88 and 1988/89 when the board certified and released seeds of low quality. The generally better performance of the CMB than the GMB in overseeing seed production may be partly attributed to the pressures given by commercial cotton growers on the organization to perform well.

Except for groundnut and cotton seed, whose distribution is undertaken by the Grain Marketing Board and the Cotton Board respectively, all commercial seed sales are undertaken by the private sector which includes cooperatives and private wholesalers and retailers. The Seed Co-op uses a system of appointed distributors which include national and local cooperatives and wholesalers. Seed is frequently supplied directly from the coop member-producer to the distributor, rather than being first directed through the coop’s centralized warehouses. The largest single distributor, accounting for some 43% of total sales, is Farmers Coop, an organization with some 4000 members. Farmers Coop serves both large-

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3 The short season varieties yield only 50% that of long season varieties yet payments for the two were exactly the same.

4 CMB certified the seeds even though the Seed Services judged them as having too low a germination rate to be certified.
scale commercial farmers and communal farmers, supplying fertilizers, equipment, and other inputs in addition to seeds. Several private companies also supply seeds together with other production inputs. One firm, Agritrade, has focused its distribution in the communal areas, operating many depots in rural areas and maintaining distributors even in the most remote areas. The firm’s trade, however, is presently limited to one region of the country.

While there are several dozen private and cooperative seed distribution companies, market competition has been limited by Seed Coop’s distributorship system which tends to give local agents monopolies over particular areas. In addition, both seed producer prices and buying prices are either controlled or strongly influenced by government. The Ministry of Trade and Commerce sets maximum seed prices and mark-ups for wholesalers and retailers. While the available evidence suggests that some traders charge prices well above the statutory maximum (especially in communal areas), seed prices in Zimbabwe are low relative to many developing countries. While the system of appointed distributors has functioned well for maize it has functioned rather poorly for other crops important to communal area farmers. As a result, it is rare to find improved seeds, other than hybrid maize, in rural shops. Less than 15% of communal farmers interviewed in one sample survey reported obtaining cotton or maize seeds from local traders, while less than 7% of such farmers reported obtaining groundnut, sorghum, or sunflower seeds from local traders.

Table 2 summarizes the mix of public, private, and cooperative interests in Zimbabwe’s seed system. It indicates the importance of public institutions in varietal development work, yet the dominance of private and cooperative interests in seed production and distribution. Even in quality control and certification, a function handled by public agencies in most developing countries, there is a mixed involvement of the public and private sectors. While there is a government seed testing service, quality inspection and certification is carried out jointly by the seed associations and certification units within the Ministry of Agriculture.

Hence, the Zimbabwe seed system is uniquely structured. Collaboration between the public and private sectors has taken a form which provides for publicly-sanctioned private monopolies or near monopolies for several important crops. A more competitive system operates only in the relatively underdeveloped seed markets for horticultural and forage seeds. While public/private collaboration appears to have brought about considerable advances in the development and spread of hybrid maize varieties, this system may have simultaneously hindered the development of commercial seed operations for other crops since the largest and potentially most profitable market has been reserved for one or very few firms. The secure market position which Seed Co-op has been given may also have contributed to its adopting a less aggressive strategy for developing seed markets for other crops.

While an appropriate mix of public and private sector activities has emerged within the Zimbabwe seed system, there is a strong imbalance within this system in terms of seed development, production, and distribution for different crops and varieties. The limited attention given by either the public or private sectors to developing, multiplying, and distributing improved varieties of millet, sorghum, and legumes, and past ineffectiveness in groundnut seed multiplication have certainly been contributing factors to the problems of food insecurity in some communal areas. The limited development of local horticultural seed/seedling production serves as a constraint for the further expansion and diversification of the country’s horticultural export industry. To counter these gaps in the seed system, measures should be adopted to facilitate imports of certain horticultural seeds and to promote local cooperative, small private company, or informal, village-level production and distribution of improved seeds for important horticultural crops.
<table>
<thead>
<tr>
<th>Crops</th>
<th>Variety Sourcing/Development</th>
<th>Seed Production/Processing</th>
<th>Seed Marketing/Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct seed import</td>
<td>Foundation/Basic Seed</td>
<td>Wholesale/logistics</td>
</tr>
<tr>
<td></td>
<td>Varieties</td>
<td>Commercial/Certified Seed</td>
<td>Promotion</td>
</tr>
<tr>
<td></td>
<td>Development</td>
<td>Seed Processing</td>
<td>Retail sales</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Price determination</td>
</tr>
<tr>
<td>Wheat</td>
<td>NA</td>
<td>M</td>
<td>Coop + P</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>Coop + P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Coop + P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Coop + P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Market Determined but Official Max.</td>
</tr>
<tr>
<td>Cotton</td>
<td>NA</td>
<td>G</td>
<td>Con</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Con</td>
<td>G</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>G</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Set by Government</td>
</tr>
<tr>
<td>Maize (hybrid)</td>
<td>P</td>
<td>M</td>
<td>Coop</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coop</td>
<td>Coop</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Coop</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Market Determined but Official Max.</td>
</tr>
<tr>
<td>Potato</td>
<td>P</td>
<td>G</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P</td>
<td>Coop + P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Coop + P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Coop + P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Market Determined</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Coop + P</td>
<td>G</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>Coop + P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Coop + P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Market Determined</td>
</tr>
<tr>
<td>Forage</td>
<td>M</td>
<td>G</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Coop + P</td>
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<td>Coop + P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Market Determined</td>
</tr>
</tbody>
</table>

Codes:  
G Predominantly Government Enterprises, Agencies, and Institutes (eg. 90% or more)  
P Predominantly Private Enterprises, Individuals, and Institutes (eg. 90% or more)  
M Mixed Government and Private Involvement (eg. significant but separate roles for each)  
C Seed or Producer Cooperative  
N.A. No formal activity.  
Con Government contracting out to private firms or farmers.
Agriculture plays a central role in the Ethiopian economy, accounting for about 45% of GDP, 85% of exports, and 85% of employment. Of a total land area of 122 million hectares, only about 6 million hectares (e.g., 5%) is planted under crops. Crop production accounts for 60% of agricultural value added while livestock accounts for the remaining 40%. Among crops, those occupying the largest areas are: teff (1.4 million ha.), maize (878,000 ha.), sorghum (815,000 ha.), wheat (554,000 ha.), and barley (550,000 ha.). As a group, cereals account for some 83% of the cultivated area, various types of beans, peas, and other pulses for another 12%, and a range of other crops (e.g., oilseeds, vegetables, forage crops) for the remaining 5%. Smallholder farmers account for most of the planted area, for 90% of foodgrain production and for 98% of coffee production, the principal export crop. The balance is accounted for by large state farms and government-created producer cooperatives.

There are as many as twenty distinct agro-ecological zones in Ethiopia where crops and cropping patterns have evolved over a long period to suit localized conditions. There is an abundance of locally adapted planted materials which are not easily surpassed by improved varieties developed by formal research institutions. This, as well as limited institutional development and inappropriate seed pricing policies has resulted in a very limited role of the formal seed industry in meeting the seed needs of Ethiopian farmers.

Ethiopia represents a case of a seed industry in a relatively early stage of development with most seeds being farmer-saved and with the limited formal sector being dominated by the public sector. However, as a result of major policy changes, there are now potentially significant opportunities for much more rapid development of the seed sector and a greater level of participation by the private sector.

**Seed Demand and Commercial Supply**

Total seed consumption in Ethiopia for 1989/90 is estimated to be about 283,000 tons, the bulk of which is accounted for by wheat, barley, teff, pulses, and maize. Table 1 outlines the level of seed consumption for different crops and indicates the proportion of seed supplies derived from commercial sources versus farmer-saved seed.

The table indicates the extremely minor role of commercial sources of seed in Ethiopian agriculture. Only for maize, sorghum, wheat, oilseeds, and vegetables (not shown) is 10% or more of planted seeds obtained from commercial sources. For such important crops as teff, barley, pulses, and millet, commercially supplied seed accounts for 2% or less of seed use. For the crops listed in the table, the aggregated share of commercially supplied seed is only 5%, with farmer-saved seed accounting for 95%. While the state farm sub-sector obtains all of its seed needs from a commercial source, it is estimated that only 2% of the seed use in the smallholder sub-sector is of commercially supplied seed.

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1 This case study is based on International Enterprise Development Group Inc. (1990) "Ethiopia Seed Corporation Market Oriented Agribusiness Assessment and Project Budget"; Agrisystems (Overseas) Ltd. (1990) "Ethiopia Seed Corporation Seed Marketing Study Final Report", and World Bank project documents.

2 All figures are for 1989/90 as reported in Agrisystems (1990).
Table 1: Seed Consumption and Sourcing in Ethiopia

<table>
<thead>
<tr>
<th></th>
<th>Tef</th>
<th>Maize</th>
<th>Sorghum</th>
<th>Barley</th>
<th>Wheat</th>
<th>Pulses</th>
<th>Oilseeds</th>
<th>Millet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planted Area (000 Ha)*</td>
<td>1400</td>
<td>878</td>
<td>815</td>
<td>555</td>
<td>544</td>
<td>556</td>
<td>183</td>
<td>142</td>
</tr>
<tr>
<td>Seed Rate Kg/Ha.</td>
<td>30</td>
<td>30</td>
<td>5</td>
<td>120</td>
<td>150</td>
<td>100</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Seed Consumption (Tons)</td>
<td>42,000</td>
<td>26,340</td>
<td>4075</td>
<td>66,600</td>
<td>81,600</td>
<td>55,600</td>
<td>3660</td>
<td>2840</td>
</tr>
<tr>
<td>% Commercially Supplied**</td>
<td>1</td>
<td>12</td>
<td>17</td>
<td>2</td>
<td>10</td>
<td>1</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>% Farmer Saved**</td>
<td>99</td>
<td>88</td>
<td>83</td>
<td>98</td>
<td>90</td>
<td>99</td>
<td>86</td>
<td>100</td>
</tr>
</tbody>
</table>

* 1989/90 Central Statistics Authority, Addis Ababa

Sources: Data Provided in Agrisystems (1990) and IED (1990)

The hypothetical demand for commercially supplied seed is considerably less than the volumes indicated in the table for seed consumption. Most of seeds need not be renewed every year. For example, tef seed needs to be renewed every five years; wheat and barley seed every four years; and open-pollinated maize and sorghum seed every two years. Taking these and other ratios into account, the hypothetical demand for commercial seed in 1989/90 was 103,000 tons. Actual seed sales in that year by the Ethiopian Seed Corporation were only 10,770 tons or about 10% of the calculated commercial seed demand.

Commercial sales of seed have declined steadily since the mid-1980's after rising during the early part of the decade and peaking at 29,375 tons in 1985/86. This decline has been due to several factors, including the serious drought and subsequent famine and dislocation experienced in several parts of the country, political instability in the northern regions, financial problems in the state farm sub-sector, the uneven quality of seeds supplied by the commercial sub-sector, and the focus of the Ministry of
Agriculture’s Agricultural Inputs Supply Corporation on fertilizer rather than seed delivery. Commercial seed supplies are concentrated among a limited few crops (Table 2), with wheat and maize seed accounting for nearly 80% of total sales during the latter half of the 1980’s. Among other crops, only for barley and sorghum have commercial sales averaged more than 1000 tons per year.

Table 2: Commercial Seed Sales by Crop*

<table>
<thead>
<tr>
<th>Crop (Type)</th>
<th>Average Commercial Sales (Tons) 1985/86 - 1989/90</th>
<th>Proportion of Commercial Seed Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>11,826</td>
<td>54.8%</td>
</tr>
<tr>
<td>Maize</td>
<td>5407</td>
<td>25.1</td>
</tr>
<tr>
<td>Barley</td>
<td>2121</td>
<td>9.8</td>
</tr>
<tr>
<td>Sorghum</td>
<td>1193</td>
<td>5.5</td>
</tr>
<tr>
<td>Tef</td>
<td>539</td>
<td>2.5</td>
</tr>
<tr>
<td>Pulses</td>
<td>435</td>
<td>2.0</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>43</td>
<td>0.2</td>
</tr>
<tr>
<td>Total</td>
<td>21,574</td>
<td>100.0</td>
</tr>
</tbody>
</table>

*Does not include vegetables for which there is virtually no domestic commercial seed production.

Source: Data from ESC Sales Department as Reported in IED (1990)

In the early part of the 1980’s, commercial seed sales were made predominantly to the state farm sub-sector. Over the 1979/80 to 1982/83 period, state farms received over 80% of the seeds supplied by the Ethiopian Seed Corporation. However, with the collapse of several components of the state farm sub-sector, seed sales in this direction have declined. Hence, over the 1985/86 - 1988/89 period, state farms received only 52% of ESC supplies, while NGO programs and smallholder farmers purchased the balance.

Structure of the Seed Sector

The development of improved seeds for cereal and other food crops began in 1966 when the Institute for Agricultural Research (IAR) was established. The adoption of such seeds remained limited

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3 An additional factor has been the quota and low fixed price grain procurement system operated by the Agricultural Marketing Corporation which has implicitly taxed grain production and reduced the incentive to use improved seeds.
to a few regions due to the absence of an overall system of seed multiplication and distribution. Under a donor-supported Minimum Package Program in Chilalo in Arsi Region, improved seeds for wheat and barley were supplied to smallholder farmers together with other production inputs under credit. The success of this Program led to its replication in other regions. However, only with the creation of the Ethiopian Seed Corporation in 1978 was an attempt made to develop a national seed industry, although still no explicit policies for the seed sub-sector were announced and no seed law of any kind was created. Jointly funded by the Government of Ethiopia and several bilateral and multilateral donor organizations, the ESC was initially administered within the Ministry of State Farms. While given nominal autonomy in 1982 as a state enterprise, the ESC continued to report to the Ministry.

Plant breeding research until very recently was exclusively in the public sector. The main institutions are the IAR and the Alemaya University of Agriculture (AUA). R&D has focused on cereal crops, pulses, and oilseeds, with a breeding objective to develop varieties which exhibit superior performance across a wide spectrum of agro-ecological zones. While these organizations have made some progress in varietal development, neither has had the capacity to produce breeder seed in quantities sufficient for multiplication. Both the IAR and AUA receive government funds for capital and operational expenditures. IAR has no mechanism for retaining revenues and no policy of cost recovery. Price for breeder or foundation seeds supplied is determined by the government.

The Ethiopian Seed Corporation accounts for nearly all of the production and marketing of locally grown seed of improved seed of major food crops. For most crops, the ESC has contracted production with state farms, with less than 5% (mainly tef) being produced by producer cooperatives. Individual smallholders and other private farmers have not been involved in seed multiplication in the past. In general, the usual stage of bulking up from breeder to foundation seed has been absent in ESC's operations. ESC has also been responsible for importing hybrid maize seeds from adjoining countries to meet its needs.

The state farms multiplying the seed have been subsidized by capital grants, deferred taxation, and other financial charges to government. The price paid to them by the ESC remained constant in nominal terms over the 1979-90 period without any differentiation being made among quality grades. In fact, no price difference has existed for grain versus seed at the contract farmer level. Such a pricing structure has led to persistent financial losses for seed producers (except for hybrid maize) and in little incentive to produce quality seed. At the same time, there has been no independent seed quality certification agency to inspect the seed procured and sold by the ESC. Multiplied seed is cleaned at five ESC regional processing plants. Such plants have operated at low levels of capacity utilization. Due to quality problems, the proportion of clean seed that ESC have been able to recover from raw seed has been low and declining over time.

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4 Virtually all of the horticultural seeds used in Ethiopia are imported. Forage seeds are not produced under ESC administration, although small volumes are produced under a livestock development project.

5 Despite ESC's 'autonomous' status, it has had no control over either its procurement or sales prices for seeds and suggestions to raise both procurement and selling prices have been repeatedly vetoed by the government. The same price has been paid for breeder, foundation, and commercial seed regardless of the cost differences implicit in the production of different types of seed.

6 See Agrisystems (1990), p.37 for data on individual crops.
The ESC's operations have been supply-oriented rather than market-oriented. No reliable estimate of commercial seed demand is recorded. The ESC has served three market segments. These are: 1) the state farm sub-sector, 2) the emergency relief sector through non-governmental organizations (NGOs), and 3) the smallholder sub-sector through the Ministry of Agriculture's Agricultural Input Supply Corporation (AISCO). Seed sales to the state farm sector have been easiest to administer given that reliable orders are issued and that the organizations (until recently) shared a common supervisory ministry. Seed sales to NGOs for their emergency and rehabilitation programs have been erratic. Some of the seed supplied (freely) may actually be used for direct consumption as foodgrains since the seed is not treated with chemicals. Sales and distribution of seeds through AISCO have been problematic with very limited penetration of the smallholder sub-sector. AISCO has apparently given greater priority to its other responsibility in distributing fertilizers. Several small trading companies have acted as distribution agents for AISCO and for imported supplies of fruit and vegetable seeds.

Selling prices for seed supplies to state farms and AISCO have remained largely unchanged over the past ten years and have been the same throughout the country despite differences in transport and handling costs. Such government-imposed pricing policies have contributed to steady and large losses on the part of the ESC and have discouraged secondary seed multiplication and distribution activities in locations far from the main seed production areas. Prices charged to NGO's (and the donors financing them) have generally been 20-40% above those charged to state farms and AISCO. The higher prices charged to NGO's have thus cross-subsidized the public sector while reducing the resources available for NGO rehabilitation activities.

Structural Adjustment and Changes in Seed Sector Organization

Beginning in 1988, the Government embarked upon a gradual program of reform within the agricultural sector and within the economy more generally. These reforms were driven by continued dismal economic performance and by growing political instability. Major reforms included the easing of restrictions on grain marketing, the lifting of restrictions on private investments in various sectors, and improved incentives for direct foreign investment. In 1990, the Government announced its intention to shift from a socialist framework to a mixed economy. Among the specific reforms announced included: the liberalization of grain marketing, providing security of land tenure, lifting of restrictions on labor mobility and private commercial farming, and emphasis on increased managerial autonomy and accountability in public enterprises. The underlying theme of the reforms was one of liberalizing production and trade and allowing competition to serve as a catalyst for improved performance.

In the seed sector, one manifestation of this more liberal economic environment has been a new joint venture between the ESC and Pioneer Hi-Bred Int'l. The joint venture, initiated in 1990, will concentrate on testing, developing, producing, and distributing hybrid varieties of maize, sorghum, sunflower, and alfalfa for local sale and eventually also for export. At least for several years, this joint venture is unlikely to have much of an impact on seed availability and farm productivity in the smallholder sub-sector. Responsibility for open-pollinated crops would remain predominantly in the hands of the IAR and the ESC.

As part of a World Bank-supported National Seed Project, many initiatives have been proposed in order to improve the functioning of the ESC and to expand private sector participation in the sector. Intended measures include: the development of a national seed policy and legislation, the creation of a
seed industry promotion unit, the decentralization of ESC operations, a program to contract out commercial seed production to smallholder farmers, pilot projects to support private seed enterprises, support for village-level informal seed systems, and the formation of a seed certification agency. The implementation and success of this project will depend upon wider political developments and economic reforms in the country.

Several lessons can be drawn from the Ethiopian experience. First, it is unrealistic to expect a single seed enterprise such as the ESC to be able to cater to the large volume and diverse seed needs of an agricultural sector such as that of Ethiopia. In the absence of competitive pressures or financial accountability the response of the ESC was to focus on supplying the state farm sector with its build-in demand and little need for seed promotion and product diversity. In contrast, the smallholder sub-sector has been largely neglected and there has been a back-log of improved varieties in the research institutions waiting for a productive outlet. Second, attention must be directed to the developmental needs of the seed sector as a whole. In Ethiopia, attention focused only on producing seeds, with little attention directed toward seed quality control and certification, toward seed promotion, and toward seed distribution. Third, the low seed selling price regime imposed on and operated by the ESC since its inception appears to have had little impact on seed demand and sales, being overwhelmed by quality factors and problems of poor access to improved seeds by smallholder farmers.\footnote{In 1990, the seed: free market grain price ratio for improved open-pollinated maize was 1.9 in Ethiopia. In comparison, the respective ratios in 1985/86 in Kenya, Malawi, and Tanzania were 4.0, 4.0, and 3.5.}

The transition from a centralized public system to a more decentralized, institutionally plural system will be an extended one in Ethiopia. A significant role for private firms in the system will occur only if economic reforms are implemented under the new political structure. At this stage of seed system development, appropriate interventions are those geared toward formulating an overall seed policy, strengthening the research base, strengthening official systems of seed quality control, restructuring the ESC, supporting local level, village-based seed production and exchange activities, and supporting pilot projects to support small private companies undertaking specialized seed production and trade.
Case Study # 6: Specialized Export-oriented Seed Production in the Private Sector

As indicated in Section 4, developing countries account for a very small proportion (e.g. 13% in 1988) of world exports of seeds with only a few developing countries having seed exports of any substantial value. Among the range of agricultural seeds, greatest success in specialized export-oriented production in developing countries has been within the category of horticultural seeds, covering vegetables and flowers. Successful horticultural seed operations have been developed in such countries as Chile, Thailand, India, Turkey, Taiwan, and Kenya with the major destination markets being the United States, Western Europe, Japan, and the Middle East.

This export trade in horticultural seeds from developing countries has been undertaken almost exclusively by the private sector, featuring multinational corporations, indigenous private firms, and/or farmer associations and cooperatives. How the private sector has organized these export-oriented operations have varied according to the technical sophisticated required to produce particular types of seeds and on whether or not the varieties produced are proprietary. This case study examines some of the variations in organizational forms developed by the private sector by drawing upon cases from the Kenyan horticultural seed industry.¹

Kenya’s favorable agro-ecological conditions, its non-tariff access to the markets of the European Economic Community, its relatively low labor costs, and its liberal foreign investment regulations have made Kenya an attractive location for European and U.S. companies to invest in export-oriented horticultural seed multiplication. About a half-dozen companies have invested in such ventures since the mid-1970’s. By the mid-1980’s some 80-90% of local production of vegetable and flower seed/cuttings was exported, with much of the remainder being planted to produce horticultural crops for export in either fresh or processed forms.² Most of the varieties of vegetable and flower seeds grown in Kenya are traditional, long-standing varieties no longer protected under U.S. or European Plant Breeders Rights legislation. As Kenya does not protect PBRs, plant breeders have not been willing to issue breeder or foundation seed to unaffiliated Kenyan operations for multiplication.

Case A: Contract Farming for Non-proprietary Vegetable and Flower Seeds

In the early 1980’s, two companies developed separate horticultural seed multiplication schemes in Busia District, near the Ugandan border. Prior horticultural production in the area had been very limited with much of the vegetable supplies in local markets originating from across the Ugandan border. Most agricultural production in the area was of maize, sorghum, and cassava for household consumption, although some farmers also obtained some cash from sales of cotton and sunflower. A large proportion of adult males have migrated out of the district for short or longer time periods in search of employment. The opportunity to produce horticultural seed under contract was very attractive to local farmers, both because of its income-generating potential as well as the potential nutritional benefits of including deseeded vegetables in household meals.


² The actual value of Kenya’s horticultural seed exports is uncertain since some seed/seedling exports are registered under product categories other than seeds. The estimated value of such trade is $3-5 million.
In 1985, the two companies had 2083 farmers under contract, producing seed crops for eggplant, okra, capsicum, chillies, cucumber, watermelon, marigold, and zenia. All production was of non-hybrid, non-proprietary varieties. The landholdings of the contracted farmers ranged from two hectares to eight hectares, although the presence of gullies and large rock formations in the area limited the cultivable area to only one or a few hectares. Horticultural seed plantings, consisting of one or two crops, typically covered 0.40 hectares. The production system for one of the firms is outlined below.

Hortitech Ltd. is a small company managed and partly owned by a Swiss agronomist who has worked and lived in East Africa for many years. The firm developed ties with the Dutch firm Royal Sluis which provides it with foundation seed. This foundation seed is tested on Hortitech's small farm before being distributed to its 600 contract farmers. Together with the foundation seed, farmers are supplied with fertilizer and chemicals, the costs of which are deducted against the delivered seed crop. Written contracts are signed indicating the crop(s) to be grown, the area to be planted, the timing of plantings and probable harvest, the costs of inputs, and the buying prices for seed. Fourteen of the company's better local seed producers were employed to serve as part-time extension workers, particularly during the planting and harvesting periods. Demonstrations were provided concerning proper harvesting and seed extraction and drying techniques.

Harvested seeds were inspected, cleaned, and weighed by the company with farmers being paid on the basis of the seed weight after cleaning and sorting is completed. During the mid-1980's farmer incomes (gross of labor costs) ranged between Ks. 2500 and Ks. 4000 per acre (for a three-month crop), depending upon the seed crops grown. Such income levels were well above those possible from competing food and cash crops in the area. Cleaned seeds were then exported to the Netherlands.

Case B: Vertically Integrated Production and Export of Chrysanthemum Cuttings

Yoder Brothers Inc. is a U.S.-based, family-owned flower breeder and multiplier with production and/or sales operations in North and South America, Western Europe, and Africa. Since the mid-1960's, Yoder has been the world's largest producer and distributor of chrysanthemum cuttings plus has played a major role in the world market for planting material for carnations. The company has more than 6000 customers world-wide, most of which are nurseries which supply consumers with potted plants or seeds.

In the early 1980's, Yoder undertook an investment in Kenya to produce chrysanthemum cuttings for export to several European markets.3 The venture would be both capital and labor-intensive, with establishment and operating costs per planted area being the highest of any agricultural production unit in Kenya and perhaps in all of sub-Saharan Africa. Initial investments in irrigation facilities, cold storage facilities, an artificial lighting system, and buildings and living facilities for staff came to Ksh. 23 million (nearly $2 million). With 11 acres put into production, the establishment costs were equivalent to about Ksh. 700 per square meter under cultivation.

By the mid-1980's, Yoder Bros.(K) was receiving about 20,000 unrooted cuttings from Yoder's nurseries in South Carolina. Within twenty-four hours of arrival in Kenya, these cuttings were planted

3 Yoder's involvement in Kenya dates to the late 1960's when an affiliated Danish firm undertook a major flower production and export investment in the country. That venture also initially focused on chrysanthemum cuttings, although technical problems in production led the company to switch to alternative crops.
in the propagation fields of Yoder (K). Cuttings for some 163 different varieties were then produced under shaded netting under a production regime featuring intensive applications of fertilizers and agrochemicals and intensive input of labor. The company employed 220 people on a full-time basis, 136 of which in field operations (eg. 11 workers per planted acre). All field workers were trained to perform specialized tasks and were paid salaries 20-40% above the minimum rural wage.

This production operation could not be done on a decentralized outgrower basis. Certain capital investment requirements pose one barrier to this. An artificial lighting system is needed for use in the evening in order to prevent the plants from flowering prematurely. Irrigation systems (and back-up) systems are needed as even a short period of water stress would result in the loss of the crop. The picked cuttings must be in cold storage within thirty minutes of picking in order to stop the growth process and kill any bacteria.

A second barrier to decentralized production is a varietal maintenance problem. Each of the 163 varieties produced must remain separated from one another throughout the production and post-harvest processes. Any mixture of varieties would undermine the entire operation. The distribution of proprietary hybrid varieties to outgrowers would also risk the company's loss of control over such varieties. A third barrier to outgrower involvement is market risk. All of Yoder's cuttings are distributed directly to nurseries in Western Europe and North America. Their demand and the available supply of individual varieties is highly variable. An individual outgrower would probably only produce one or relatively few varieties and thus be exposed to considerable risk. Every two weeks the central office of Yoder Brothers in Ohio instructs the Kenyan operation about required adjustments in plantings and pickings. On some occasions, the Kenyan operation is instructed to uproot certain varieties, given unfavorable market conditions for them.

In conclusion, these cases have illustrated some of the alternative modes for organizing 'custom' seed production for export. The relative suitability of different modes will depend upon the technical and economic characteristics of the specific commodities and their production. For all but the production of hybrid or proprietary varieties, there may be scope for basing production on smallholder outgrowers, providing an important source of income as well as employment in particular regions. Relatively remote regions may in fact be more attractive to private firms, given a reduced risk that the commodities (eg. vegetables) or their seed will 'leak' into alternative marketing channels.
Case Study # 7: Informal Seed Distribution: An Illustrative Case from Peru

While significant investments in research and seed production have been made in many developing countries, prior experience in spreading improved seeds to smallholder farmers through formal seed organizations has been mixed due to problems in seed delivery mechanisms. In response, governments and donor agencies have typically sought to either to design and establish entirely new channels for seed distribution or else to transfer centralized formal systems from the public or parastatal sector to the private sector.

However, in most countries, much of the seed used by smallholder farmers is either produced and conserved by the farmers themselves or obtained from within decentralized, less formal seed exchange systems. The available evidence suggests that much of the spread of HYVs of rice and wheat in South Asia occurred within informal seed distribution networks rather than through the formal seed distribution channels established by parastatal or private firms. There is a wealth of long-term, successful experience with the diffusion of seed within the informal sector. In many cases, improvements can be made in such systems and the contributions of formal research and foundation seed production operations can be enlarged by better linking formal and informal seed sub-systems.

Despite the significance of informal seed distribution systems for smallholder farmers, there has been relatively little research on how such systems operate and on prior attempts to better link such systems with formal research and seed production operations. This limited understanding of informal seed distribution systems has re-enforced the tendency for policy-makers and development organizations to focus their attention on expanding, rehabilitating, or restructuring formal seed systems rather than building upon existing informal systems. In this case study, the nature and appropriateness of informal seed distribution systems is briefly discussed and one case where formal and informal seed systems have been effectively linked is examined.

Nature and Appropriateness of Informal Seed Distribution Systems

In contrast with formal seed systems which operate at a national, state, or project level, informal seed systems operate mainly although not exclusively at the community level. Such systems are typically quite flexible, involving a variety of different exchange mechanisms which facilitate the transfer of seeds among households (e.g., cash, barter). Seed transactions are generally quite small compared with seed sales of formal seed organizations. Informal systems can be regarded as traditional in that they normally involve long-standing, well-established practices and links between seed producers and consumers.

Informal seed systems are most appropriate and often dominant under the following circumstances:

1) where the farming community is located in a remote location. This inhibits farmer access to markets and seed distributor access to the area. Both poor communications and high transport costs inhibit links between formal seed systems and farmers located in remote locations.

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1 See Pray (1990) for India and Tetlay et al. (1990) for Pakistan.

2 Two important exceptions are the studies by Cromwell (1990) and Garay et al (n.d.).
2) where production is undertaken within a narrow agro-ecological zone or where soils and/or weather conditions are highly heterogeneous (and variable). These conditions provide difficulties for formal seed enterprises to effectively understand and meet the local farmers' seed requirements. Farmers are expected to have a much more detailed knowledge about the suitability of different varieties for narrow agro-ecological zones.

3) where the crop(s) involved are self-pollinated, are subject to only slow genetic degeneration, and are highly storable. Such properties facilitate the maintenance of relatively high quality seed and require farmers to regenerate their seed supplies only periodically rather than every one or few years.

4) for crops in which the seeding rate is very high, yet the seed multiplication factor is relatively low (eg. require several generations of multiplication to satisfy seed requirements). Community-based seed multiplication and distribution can potentially save on transport costs as well as production costs for seeds of such crops.

Based on the above, it would appear that informal seed distribution systems would be especially appropriate and empirically dominant: a) within mountainous areas (eg. factors 1 + 2), b) in relatively cool and dry areas (eg. improved local seed storability) and c) for such crops as wheat, rice, beans, groundnuts, and potatoes (eg. factors 3 + 4). With the exception of wheat, these listed crops are also the staple food crops of smallholder farmers in many locations.

Small Farmer Potato Seed Distribution in the Peruvian Highlands

In the highland areas of Peru, potatoes are the primary food crop as well as the most important cash crop. Potatoes are grown by some 60% of the farm families in these areas and cover approximately 30% of the cultivated land. The small-scale hill farmers constitute approximately 80% of the potato producers in Peru and account for about 40% of the national potato production. Because of the narrow agro-ecological niches within the highlands, the considerable risk of agricultural production in these areas (eg. from drought and frost), and the varied culinary tastes of farmers and consumers, several hundred indigenous potato varieties are grown. Some modern hybrid varieties are also grown, although this is more common in production at lower altitudes where there are stronger links with urban markets. Within the highland areas, the road network is poor and some production areas are completely cut off from vehicular access.

Until the early 1980's, seed potato programs in Peru focused on supplying improved seeds to large-scale commercial seed growers, located either in the Central Highlands or along the coastal area. It was hoped that this improved seed would eventually be diffused into the production systems of small-scale hill farmers. However, the links between the large-scale commercial and small-scale highland potato sub-sectors were far too weak for an effective diffusion of the improved seed. Small farm communities benefitted little from these programs. As a result, in 1983 a special seed project was developed involving the National Institute for Agricultural Research (INIAA), the International Potato Center (CIP), and the Swiss Development Cooperation, focused on linking formal research with the informal seed distribution systems within the highlands.

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3 This section is based on Cromwell (1990, Chapter 6) and Scheldegger et al (1989).
The first stage of the project was to examine the existing informal seed distribution system which served about 90% of the potato production area. The investigation found that farmers mainly conserve seed from season to season, periodically obtaining fresh seed in small quantities for regeneration. Rates of seed replacement were found to differ by altitude and variety, although in the main production zone (eg. between 3200 and 4000 m), seed replacement occurs every seven years for modern varieties and less frequently for native varieties. At lower altitudes where seed degeneration is faster, fresh seed is obtained more frequently. A common practice of farmers is to move seeds between fields at different altitudes.

As for the source of seeds for seed replacement, only 11% of the sampled farmers reported obtaining seeds from commercial seed growers. In contrast, nearly 40% of farmers obtained seed from other local farmers either living in the same locality or in other nearby areas. Another 27% were obtained from village markets or merchants.

As part of the new seed program, laboratories and research stations were set up in five locations within the highlands to produce pathogen-free basic (eg. foundation) seed of the most popular twenty modern and sixteen native varieties. This basic seed was then sold to farmers or farm communities for them to multiply and distribute. While the basic seed was supplied via the extension service or via state or non-governmental projects, the subsequently organizational issues were left entirely up to the individual communities. Basic seed was sold to farmers in 20 kg. bags, a quantity which was common in informal seed transactions. Farmers were expected to multiply the seed, save most for their own use, and distribute the remainder to relatives and neighbors. Individual communities were sold some 200 kgs. of basic seed to develop community seed multiplication plots. Again, it was expected that the multiplied seed would be retained within the community as well as sold/exchanged with neighboring communities. Instead of imposing any formal certification scheme, the program would continue relying upon the traditional 'neighbor certification' system.

A follow-up study undertaken after two years of the program found that the volume of seed production had expanded rapidly and that the improved seed had been widely diffused among many farmers and neighboring communities. Seed which was originally supplied to 6 communities and 15 individual farmers had reached 14 communities and 191 individual farmers. On-farm research trials indicated that seed quality had been maintained and that a large proportion of farmers obtained increased yields by having disease-free seeds.

Several factors contributed to the success of this program. First, the formal research system was able to provide disease-free basic seed of several varieties preferred by local farmers. Second, the farm communities involved had already had considerable experience in seed multiplication and conservation so that the quality of seed coming out the system was not at all inferior to that which would emerge from a formal certification system. Third, there was already a well-functioning network of seed exchanges within the local economy, involving both farmers and traders, which facilitated the diffusion of the improved seeds. Fourth, farmers make limited demands on the system given that seed regeneration is phased over seven years or more and only small quantities are required at any one time.

In conclusion, informal seed distribution systems are both widespread and long-standing and are the dominant source of off-farm supply of seed to smallholder farmers in many countries. Although not providing a complete substitute for formal seed supply systems, such informal distribution systems are an important alternative and supplement to such systems especially for self-pollinated crops and for spreading improved seeds to smallholder farmers operating in remote or mountainous regions. As the Peruvian case shows, there is considerable potential to combine the strengths of formal research and seed production with informal distribution systems to improve the performance of each.
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