Hybrid seed and the small-scale farmer: Economic and policy issues for developing countries

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Abstract

Despite the widespread belief that hybrid technology is inappropriate for small-scale farmers, recent evidence suggests that hybrid seed represents a low-cost option for increasing yields of maize in developing countries. This paper reviews economic and policy factors which will influence the success of efforts to promote adoption of hybrid technology among small-scale maize farmers.

1. Introduction

Maize production in developing countries will have to increase at an unprecedented rate over the next 15 years if maize supplies are to keep pace with projected rapid increases in demand for food and especially feed (FAO). Given limited prospects for additional area expansion, the main engine of future production growth will have to be yield increases. Although a number of avenues are open for increasing maize yields, expanded use of improved germplasm offers one of the most effective and cheapest opportunities. In many developing countries, use of improved maize varieties and hybrids is still modest. Of approximately 58 million ha planted to maize in developing countries (not including temperate production zones), just over 24 million ha are sown to improved materials. Of this area, about half is sown to hybrids and about half to improved open-pollinated varieties (OPVs) (López-Pereira and Morris).[1] Expansion of the area under improved materials thus represents a major potential source of future yield increases. This paper addresses a number of economic and policy issues that will influence the success of a strategy to expand the area under hybrid maize. While the benefits of hybrids have been convincingly demonstrated in commercial maize producing countries of the industrialized world, it is not so clear that a hybrid-based strategy can be equally effective in the small farm agriculture that characterizes many developing countries.

2. Brief history of maize breeding strategies

Hybrid maize was first introduced in the USA beginning in 1933. Ten years later, nearly all of the American corn belt was planted to hybrid seed. Adoption of hybrids was the main factor leading to the takeoff in maize yields which occurred in the USA during the 1930s, some 20 years before chemical fertilizer and pesticides were widely adopted (Figure 1) (Byerlee and López-Pereira). During the post-War years, hybrid maize technology spread to other commercial maize producing countries. In western Europe and in temperate zones of South America (Argentina, Chile), adoption of hybrids proceeded rapidly in the late 1940s and early 1950s. About a decade later, large-scale commercial farmers in eastern Africa (Kenya), southern Africa (South Africa, Zimbabwe), and tropical South America (Brazil) also began to take up hybrids.

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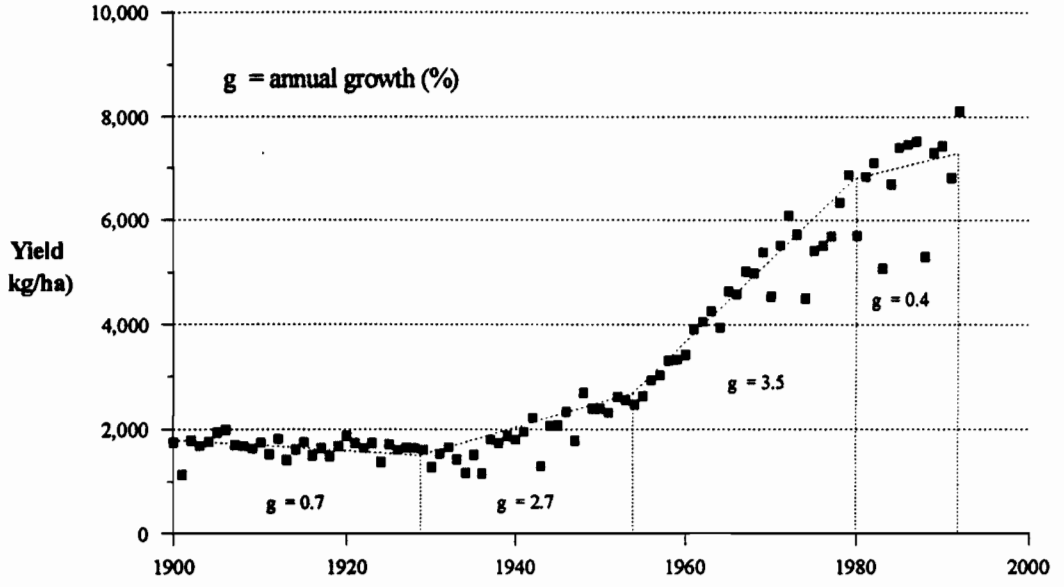
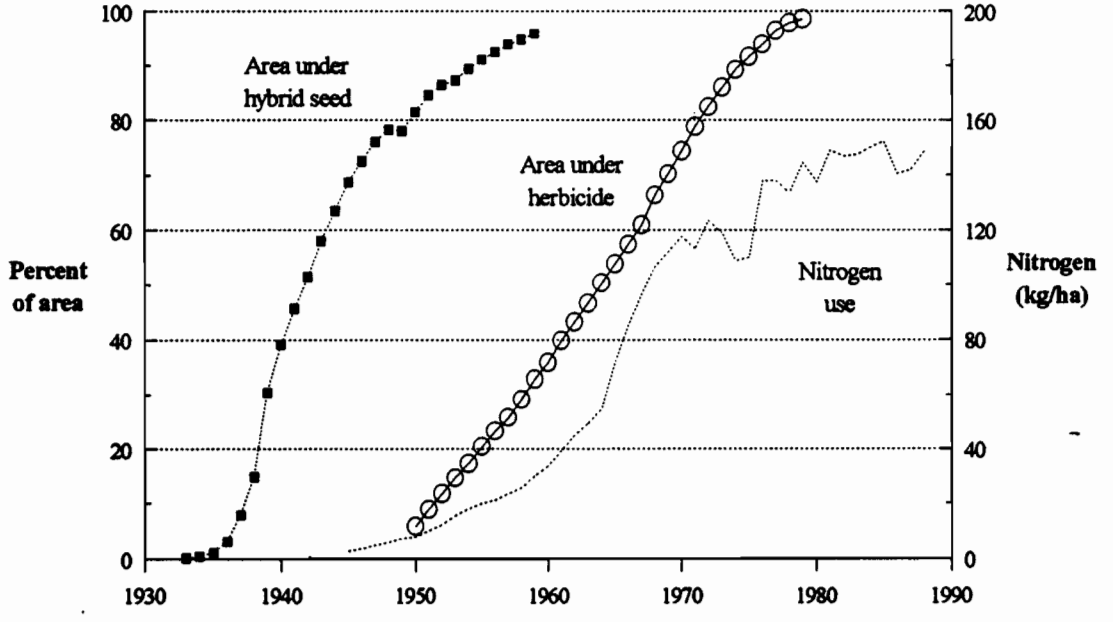
[1] Hybrids (produced by crossing two or more genetically homogeneous inbred lines) differ from open-pollinated varieties (which are genetically diverse and self-replicating). Since hybrids do not "breed true," farmers who grow hybrids must purchase fresh seed every year, while farmers who grow OPVs can save seed from each crop for replanting the following season.



Source: Brown (1966), and FAO data.

Figure 1a. Maize yields in USA, 1900-92.



Sources: Hybrid seed - USDA Agricultural Statistics (various years).
Herbicide, nitrogen - Sunquist et al. (1982), updated in Munson and Runge (1989).

Figure 1b. Trends in hybrid seed adoption, herbicide adoption, nitrogen use on maize in USA, 1933-89.

During the period when hybrid maizes were first being adopted by large-scale commercial farmers, efforts were also made to introduce hybrid maize technology into small farm agriculture in developing countries. Many of these efforts were stimulated by foreign assistance programs inspired by the success of hybrid maize technology in the USA. In spite of high expectations, however, these programs met with limited success, and in most developing countries the proportion of maize area sown to hybrids remained modest.

At the time of the establishment of the International Maize and Wheat Improvement Center (CIMMYT) in 1966, international maize breeding efforts were focused primarily on the development of hybrids. However, during the late 1960s the attention of CIMMYT maize breeders shifted to OPVs. The shift in emphasis from hybrids to OPVs appears to have been stimulated by several widely held beliefs:

- hybrid technology is not appropriate for small-scale farmers, especially since it requires annual seed purchases;
- hybrids cannot succeed without the support of a sophisticated seed industry; and
- seed of OPVs can be produced with simple technology, and once distributed to farmers, will travel from farmer to farmer (as was then occurring with the high-yielding varieties of rice and wheat).

At the same time that CIMMYT was shifting its germplasm improvement efforts to focus on OPVs, many national maize research programs also were beginning to concentrate on population improvement activities, with the ultimate objective of producing improved OPVs. The widespread shift in breeding focus was reflected at the global level in a marked increase in the proportion of OPVs released during the 1970s (López-Pereira and Morris). The results of this OPV-led strategy were mixed. A few outstanding successes were realized, as in Thailand, where improved OPVs were adopted on most of the maize area. More commonly, however, the adoption of improved OPVs was less extensive than expected. Seed supply and quality were often inadequate, in many cases because private seed companies showed little interest in producing and marketing a product over which they could not easily establish enforceable proprietary rights. As a result, OPV seed production was usually left to inefficient parastatal seed companies or assigned to community development projects lacking in technical expertise. Even where improved OPVs were initially adopted, few farmers replaced seed on a regular basis.

Meanwhile, as efforts to promote improved OPVs faltered, a number of success stories emerged to show that hybrid maize could be adopted profitably by small-scale farmers. In Kenya, Zambia, and Zimbabwe, adoption of hybrids by small-scale farmers resulted from a "spillover" out of the commercial farming sector. In all three of these countries, hybrids were initially targeted at large-scale commercial farmers, but when the superior performance of the commercial hybrids caused them to be sought out by small-scale farmers, seed companies recognized a potential new market and adjusted their packaging and marketing strategies accordingly. Other countries in which hybrids were widely adopted by small-scale farmers included El Salvador, Venezuela, China, and India.

Most of the early success stories featuring adoption of hybrid seed by small-scale farmers had several features in common:

- when grown under farmers' conditions, hybrids developed by public sector research institutions provided a large yield advantage compared to local varieties;
- private seed companies or cooperatives (public seed companies, in the case of China) were able to produce and market quality hybrid seed at affordable prices; and
- public extension services played an important role in widely demonstrating the technology and in educating farmers about the need to replace seed annually.

Perhaps the single most important lesson emerging from the early success stories was that hybrid maize can perform well under a wide range of production conditions and levels of management. With the realization that hybrid maize technologies can be appropriate even for small-scale farmers, attention within CIMMYT and in many national breeding programs shifted back to hybrids. This shift in focus was subsequently reflected in the mix of products coming out of national breeding programs; since 1985, the number of hybrids released has increased relative to the number of OPVs, and sales of hybrid seed have risen dramatically (López-Pereira and Morris).

3. Economic factors influencing the adoption of hybrid seed

The farmer's decision to adopt hybrid seed is influenced by four main economic factors:

a) Price of hybrid seed

Since hybrid seed must be purchased annually, its price is potentially important in the adoption decision. (In order to facilitate comparisons, seed prices are conventionally

expressed in terms of the number of kilograms of maize grain that must be sold to pay for one kilogram of seed, known as the *seed-to-grain price ratio*. The price of hybrid seed depends on various factors:

- *the type of hybrid.* The seed yield of parental materials used in producing hybrids varies enormously, resulting in large differences in production costs. Seed yields of the inbred lines used to produce single cross hybrids tend to be very low, making single cross hybrids relatively expensive to produce. In contrast, seed yields of the composite materials used to produce top-cross hybrids and varietal hybrids tend to be somewhat higher, making top-cross hybrids and varietal hybrids relatively inexpensive to produce. These differences in production costs are reflected in the prices charged for different types of hybrids (Figure 2).

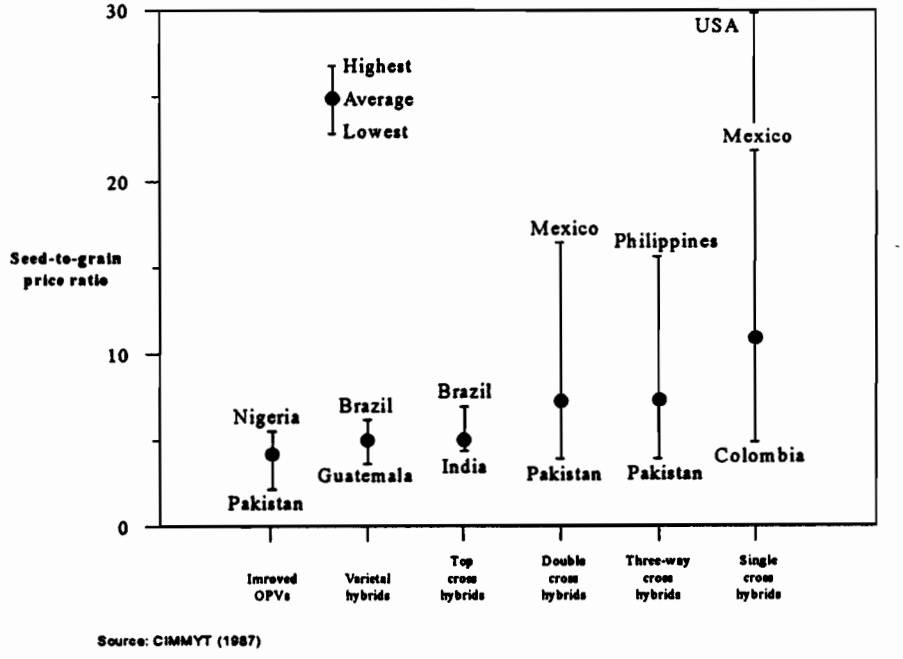


Figure 2. Maize seed-to-grain price ratios, by seed type.

- *the costs which must be covered by the price of hybrid seed.* If hybrid seed is produced from inbred lines developed by the public sector, research and development costs do not have to be reflected in the price of seed. Likewise, if hybrids are promoted extensively through public sector extension programs, marketing and promotion costs borne by private companies are generally low.

- *the structure and competitiveness of the seed industry*. A seed industry characterized by companies which actively compete for market share is likely to be more efficient than one made up of companies which enjoy monopoly or oligopoly power. Experience has shown that competitive seed industries are more likely to develop if the public sector provides a source of improved germplasm and supports extension and promotion activities.

Table 1 presents information on prices of hybrid maize seed in selected countries. In the USA, the seed-to-grain price ratio is now close to 30:1, but during the 1930s when hybrids were initially adopted, it ranged from 5:1 to 8:1. In a number of developing countries where hybrid seed has been widely adopted by small-scale farmers, seed-to-grain price ratios currently range from 4:1 to 6:1.

Table 1. Seed-to-grain price ratios and adoption of hybrid seed in selected countries, 1990

Country	Seed-to-grain price ratio for a common hybrid[a]	Percent of maize area sown to hybrid seed
Zambia	2.8	72
India (winter maize areas)	4.2	75
Venezuela	4.4	91
El Salvador	4.6	55
Zimbabwe	6.5	96
Mexico	7.1	8
Indonesia	11.3	13
Thailand	15.1	20
Philippines	16.7	5

[a] Ratio of price of hybrid seed (usually a double cross hybrid) to commercial price of maize grain.

Source: CIMMYT survey.

Differences in seed prices can be explained partly in terms of differences in production costs. For example, today's high seed prices in the USA reflect the widespread use of single cross hybrids. However, other factors can also contribute to high seed prices. In the USA, seed production costs comprise only about 30% of the final sales price; the rest consists of R&D, marketing, and promotion costs. By contrast, over 80% of the final sales price in Zimbabwe consists of production and on-farm processing costs; until recently, R&D, marketing, and promotion costs borne by the seed companies were negligible, since these services were provided largely by the public sector.

Wherever hybrid maize has been widely adopted by small-scale farmers, seed-to-grain price ratios have been in the range of 4:1 to 6:1. This would appear to indicate that low seed-to-grain price ratios (probably on the order of 10:1 or less) are necessary to encourage farmers to adopt hybrids during the development phase of the seed industry, when the market for hybrid seed is first established. At these low seed-to-grain price ratios, seed costs contribute only a small share of the variable cost of production.

b) Seed rate

Another important variable which can greatly affect the cost of using hybrid seed is the seed rate. Although standard seed rates for maize usually fall in the range of 20- 25 kg/ha, in some instances they are much higher. In Indonesia, for example, seed rates average over 40 kg/ha because farmers overplant in order to compensate for expected losses from insect attacks during the seedling stage. In hill areas of northern Pakistan, farmers frequently sow 80-100 kg/ha of seed in order to provide both grain and fodder from thinnings. In parts of central India and southern Africa, early season drought can lead to poor emergence, creating the need to replant one or more times. In all of these situations, the use of hybrid seed may be unprofitable unless ways are found to reduce the need for high seeding rates.

c) Cost of capital and risk

To be attractive to farmers, hybrid maize must not only generate additional income sufficient to repay the higher cost of the seed, but it must also provide an extra return to compensate the farmer for the risk taken in planting an unfamiliar material. Small-scale farmers, particularly those who rely on their own production for an important share of household consumption needs, often place a high value on food security. Studies have found that a marginal return of at least 100% often is needed to make investment in a new technology attractive to farmers. Some seed companies figure on a much higher marginal return of at least 300% in setting prices for hybrid seed (McMullen). Under such a pricing strategy, at least three quarters of the additional benefits associated with the new hybrid are captured by farmers.

d) Yield gains from hybrids

On the benefit side, the most important variable determining the attractiveness of maize hybrids is the yield advantage they offer compared to the farmer's current material. In areas where hybrids are replacing unimproved local varieties (e.g., parts of eastern and southern Africa, Central America), yield increases on the order of 40-50% are quite

realistic. In areas where hybrids are replacing improved OPVs (e.g., Thailand, parts of India), it may be difficult to achieve yield increases of more than 20-25% over the levels currently being achieved by farmers.

Although it is widely believed that the yield advantage of hybrids will be expressed only with good management, plentiful water, and high levels of purchased inputs (especially fertilizer), recent evidence suggests that hybrids can be profitable even in marginal environments and under low management (Byerlee and Heisey). Given the paucity of on-farm studies, it is difficult to draw firm conclusions about the conditions under which hybrids are likely to outperform farmer's materials. Clearly there is a need for more extensive testing of hybrids under farmers' conditions in order to assess their yield advantage at the farm level.

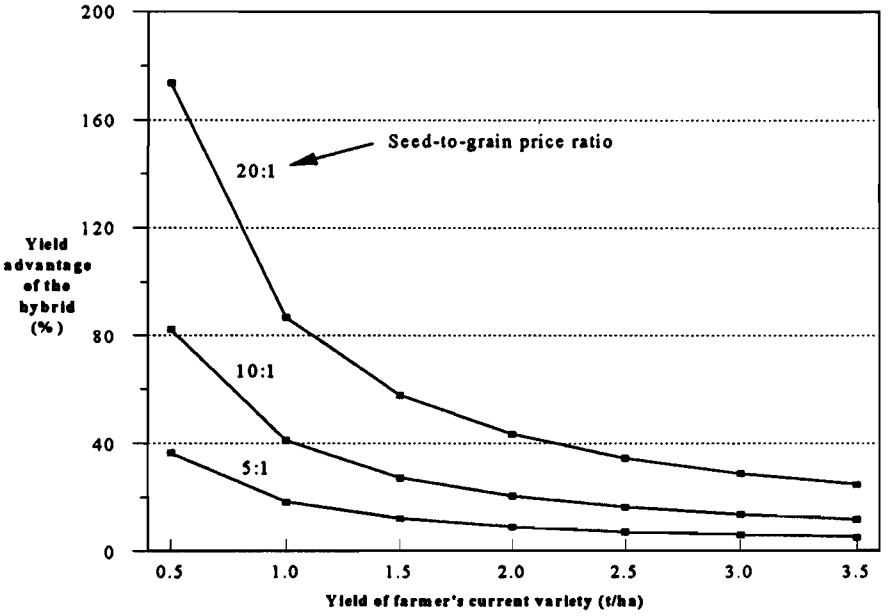


Figure 3. Yield advantage over farmer's current variety required to compensate additional cost of hybrid seed and generate 100% marginal return to investment.

Putting together all of these variables -- seed price, seed rate, yield gains, cost of capital and risk -- we can derive break-even yield gain curves to show the likely profitability of adopting hybrid maize. Break-even yield gain curves depict the set of minimum percentage yield increases (computed across a range of yield levels) which a hybrid must generate in order to compensate the farmer for the higher seed cost and increased risk. Figure 3 shows

break-even yield gain curves for three seed-to-grain price ratios. At a high seed-to-grain price ratio of 20:1, the yield increase generated by the hybrid must be very large in order for adoption to be attractive, especially if current yields are low. At a low seed-to-grain price ratio of 5:1, the yield increase generated by the hybrid can be much smaller.

4. Policy and institutional issues in promoting hybrid seed

With certain notable exceptions, public and parastatal seed companies in developing countries have not been particularly proficient at developing, producing, and distributing adequate quantities of high quality maize seed. Therefore, if future efforts to increase maize production in developing countries are to involve greater use of hybrid technology, the private sector probably will have to assume a more active role in the seed industry.

Since private companies by definition are in business to generate profits, they will become active in the seed industry only if it is economically attractive to do so. Key factors that can influence the profitability of the seed industry are discussed in this section. Because profit opportunities change depending on the maturity of the seed market, it is useful to organize the discussion around two types of seed markets representing different stages of development: *emerging seed markets*, in which farmers are adopting hybrid seed for the first time, and *mature seed markets*, in which most farmers already use hybrid seed and periodically replace older hybrids with newer hybrids.

Emerging seed markets

In emerging seed markets, public breeding programs carry out most of the applied research needed to develop improved OPVs and hybrids. This was true even in the world's largest hybrid maize seed market, the USA, where up until 1950 most of the inbred lines used in producing commercial hybrids were developed by breeders working at public universities. Rather than concentrate on research, the first successful seed companies in the USA placed most of their effort in seed production and marketing. Similar alliances involving public sector R&D and private sector seed production and marketing were instrumental in the emergence of thriving hybrid maize seed markets in Brazil, El Salvador, Venezuela, Kenya, Malawi, China, and India. Significantly, in nearly all of these countries public support to research was accompanied by public support to extension and farmer education, as government extension services played a major role in publicizing the benefits of hybrids and promoting their use.

In emerging seed markets, public policies have often been important in providing incentives for private companies (state companies, in the special case of China) to become involved in seed production activities. These incentives have typically included:

- provision of free access to improved populations and inbred lines generated by public research institutions, as well as information about the performance of these materials;
- provision of credit and technical assistance to companies to invest in seed production (since hybrid seed production is skill intensive, technical training programs are often important for successful seed production);
- introduction of realistic policies governing seed certification that do not restrict the timely availability of quality seed to farmers; and
- establishment of liberal foreign investment laws and seed import policies to facilitate foreign participation in the seed industry (multinational seed companies are often an important source of new technology for seed production).

We have not included in this list plant varietal protection laws and other forms of intellectual property rights (IPR) legislation. In our experience, these have not been very important in stimulating the emergence of seed markets during their initial stages of development.

Mature seed markets

In mature seed markets, incentives are often substantial for private companies to assume a larger role in R&D activities. In mature markets, most farmers are already familiar with hybrids and are willing to pay higher prices for quality seed. Furthermore, farmers expect that new, superior hybrids will be released periodically, leading to steady increases in yields. Thus, there is more scope for private companies to invest in R&D in order to develop branded products, as well as to invest in marketing and promotion in order to differentiate their products in the marketplace.

In countries with well-established and dynamic private seed industries, public breeding programs must redefine their role so as to complement the activities of the private sector. The experience of many industrialized countries suggests that if public breeding programs do not redefine their roles, they will be left trying to compete with private companies in a contest in which the rules inevitably favor those who pay greatest attention to the bottom line (i.e., profits). Although public breeding programs may be able to adopt some of the

practices of private companies (including charging fees for their products), there is usually a limit to the degree to which this will be possible. Thus, public breeding programs must be willing to cede responsibility for some of their former functions and to concentrate on activities which private companies are unlikely to undertake. Activities which the public sector can perform in a mature seed market include:

- concentrating on the development of OPVs or hybrids for farmers and regions which do not allow a sufficient profit to interest the private sector (usually these farmers are located in marginal production regions);
- providing special trait materials (e.g., materials with resistance to specific abiotic and biotic stresses) that require a considerable investment in plant breeding over time and that enhance the stability and social benefits from private sector hybrids developed from using these special trait populations; and
- providing information (based on multilocational testing) about yields and other traits of private sector hybrids.

Other potential roles of the public sector are more controversial:

- evaluation and approval for release of private sector hybrids. Although responsibility for this important function is usually assigned to government-appointed varietal certification boards, in cases where public breeding programs are seen as competing with the private sector, government-appointed bodies often are charged with favoring materials produced by public breeding programs and discriminating against materials submitted by private companies;
- charging royalties for the use of public sector inbreds and hybrids. Some countries in Latin America and Asia are now actively experimenting with this approach, but there is a danger that a "profit driven" public sector will target its research to compete with the private sector, rather than play a complementary role as discussed above; and
- implementation of IPR legislation to provide greater protection to private sector R&D. Intellectual property rights are more important in mature seed industries than in emerging industries and may be especially important in facilitating the transition to single cross hybrids. However, the real importance of IPR laws is not that they stimulate investment by the private sector in R&D, but rather that they facilitate the transfer of new technologies from other countries.

5. Conclusions

Many developing countries are experiencing an unprecedented surge in the demand for maize. One of the major potential sources of future productivity growth needed to meet this demand will be hybrid technology. It is now well established that hybrid maize can and will be adopted by small-scale farmers, provided good quality seed is readily available at reasonable prices. We have noted the wide variation in prices of hybrid seed, even seed of the same type of hybrid. Since evidence from a number of countries suggests that seed-to-grain price ratios on the order of 10:1 or less may be necessary to encourage widespread adoption of hybrid maize, it is important to understand the factors which affect seed pricing strategies. Maintaining low seed-to-grain price ratios requires an efficient seed industry, strong support from public-sector R&D in the form of inbreds and finished hybrids, and active promotion of hybrid technologies by the public extension service.

Although a variety of institutional arrangements involving different degrees of public and private sector participation have proven effective in fostering the emergence and establishment of hybrid seed markets, extensive government subsidies have almost invariably been necessary during the initial stages of market development (even in industrialized countries which today feature thriving seed industries). Generally speaking, during the initial stages of market development private companies have a comparative advantage in seed production and marketing activities, while public institutions have a comparative advantage in R&D, in educating farmers about hybrids, and in promoting the use of hybrid seed. Incentives to invest in research change as seed markets mature. In emerging seed markets, potential returns to R&D are limited, and public breeding programs must be expected to take the lead in developing not only basic germplasm, but also more finished products suitable for immediate distribution. As seed markets evolve and mature, however, incentives for private sector investment in R&D increase, and private seed companies can be expected to assume a greater role in developing products specifically designed for well-identified niches. When this happens, institutional arrangements must evolve to accommodate the changing role of the private sector, and changes will usually be required in IPR laws, as well as in procedures for varietal testing and release. As private companies assume a greater role in R&D, public research organizations frequently will have to reorient their activities to place greater emphasis on the development of basic germplasm, rather than finished products.

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