AN ADOPTION-BASED ROYALTY SYSTEM FOR FUNDING PRIVATE-SECTOR PLANT BREEDING IN AFRICA

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Introduction

Promoting agricultural productivity growth via genetic improvement has been a cornerstone of international development strategies for decades. Many investments have paid handsome dividends over the years, most notably efforts associated with the Green Revolution. Yet despite billions of dollars in development assistance expenditures, significant cross-country differences in agricultural productivity continue to exist – both between industrial and developing countries, as well as between (and even within) developing countries. The persistence of these productivity gaps, and the seeming inability of historical public sector-dominated approaches to promote agricultural development in some regions, have led a growing number of analysts, donors, and policy makers to explore non-traditional means of promoting private sector-led agricultural development in lagging regions.

Interest in finding a new means of promoting agricultural development is particularly strong for sub-Saharan Africa, where cereal yields are generally far lower than in other regions,[1] and only about one-quarter of cropped area is planted in improved varieties (Renkow and Byerlee 2010). A number of causal factors have been advanced to explain this yield gap between Africa and the rest of the world. These include deficiencies in various forms of infrastructure, both physical and institutional, that impose substantial transactions costs on participants in agricultural markets; poor soils (and poor soil management); unfavorable and variable climate; and a policy environment that has often tended to retard, rather than facilitate, the ability of farmers to pursue sustainable farming practices.

Against this backdrop, calls for new approaches to jump-starting the agricultural development process in Africa have been particularly acute, most recently culminating in significant interest in so-called agricultural pull mechanisms (AGPMs). The basic idea behind AGPMs is to use external (donor) funds to entice private firms into investing in development of research-based agricultural inputs in situations in which private investment is low or non-existent. In targeted situations, the limitations on private investment come in the form of private firms being unable to recover fixed investment costs due either to the public good nature of the commodity in question (specifically, its non-excludability), or because of small market size (Masters and Delbecq 2008).

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[1] Hess (2010) reports that average cereal yields in sub-Saharan Africa were 1.2 t/ha for the period 1999-2008, as compared with average yields of 2.5 t/ha, 4.2 t/ha, and 2.2 t/ha in South Asia, East Asia Pacific, and Middle East/North Africa, respectively.

Efforts to implement AGPMs have not yet been attempted in Africa; but interest in implementing such mechanisms has intensified with the initiation of a highly publicized Advanced Market Commitment (AMC) for pneumococcal disease vaccines. Through this AMC, donors have committed $1.5 billion to pay vaccine makers for a set number of doses to be developed at a negotiated price per dose that is sufficiently remunerative to encourage the developers to produce the vaccine. Those doses are then made available to the public at a small fraction of the price – a price that is affordable to those vaccinated, but far lower than the price that would have covered the fixed costs of developing the vaccine (Barder, Kremer, and Levine 2005).

AMCs are best suited to situations in which a very specific technology product (e.g., a vaccine) is required to address a very specific problem (e.g. prevention of a particular disease) whose public benefits greatly outweigh private benefits absent any intervention (Kremer and Zwane 2005; Masters and Delbecq 2008). The uncertainties involved in the process of seed-based agricultural innovation – both in terms of the multi-factorial nature of the problem(s) to be addressed and the pattern of uptake of the innovations – contribute to a lack of specificity that would appear to limit the efficacies of agricultural applications of AMCs in general (Elliott and Hoffman 2010).[2]

Instead, some sort of "proportional prize" mechanism that rewards technology developers in proportion to uptake of agricultural innovations would appear to be a more promising approach for promoting seed-based agricultural technologies. Such a mechanism – an approach which will be termed here an adoption-based royalty (ABR) system – has been proposed by Traxler (2010):

> *A "seed market guarantee" mechanism could be used to ensure that companies receive royalties from each hectare planted to varieties that they develop and distribute – whether farmers planted newly purchased seed or saved seed from the previous harvest. This would effectively create a guaranteed market where none exists today because of the impossibility of protecting the intellectual property that is embodied in the seeds of self-pollinating crops... The prize is awarded only if farmers adopt the company's variety, providing a strong direct incentive to understand farmer preferences and to make seed available... (The) system could be applied to self-pollinating, or even vegetative crops since the royalty award does not depend on annual seed purchase* (Traxler 2010).

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[2] Note that prizes might be a reasonable approach to finding solutions to important (and as of yet untreatable) diseases like Xanthomonas wilt disease that affects bananas in eastern and central Africa (Byerlee, pers. comm.)

The appeal of a prospective adoption-based royalty system lies in the seemingly straightforward way it would meet the interests of the key stakeholders in the agricultural development process. Farmers stand to benefit from the greater availability of productivity-enhancing agricultural technologies. The provision of new incentives to the development and dissemination of improved varieties should be attractive to donors interested in promoting private sector-led agricultural development. And from the standpoint of both current and prospective private seed companies, ABR payments compensate for their inability to capture IPR rents via payments in lieu of unrecoverable R&D investments. Importantly, the fact that payments are made to any developer of improved varieties on the basis of observed adoption accords well with the contention of Masters and Delbecq (2008) regarding proportional payment of prizes: Firms' subjective assessment of their probability of research success *vis-à-vis* other competing firms need not dissuade any potential seed companies from making R&D investments, which would be the case with winner-take-all prizes.

This paper explores the mechanics of implementing an adoption-based royalty system focused on improved seed varieties in an African context.[3] I begin by providing a thumbnail sketch of the basic motivations and constraints characteristic of key actors in the process. Subsequent sections of the paper discuss the information needed to implement such a system, potential pitfalls that would have to be overcome, and where (and under what conditions) an ABR system is likely to be most successful in promoting agricultural development. Some concluding comments are found in the paper's final section.

The Agricultural Innovation Problem in a Nutshell

At the outset, it is useful to consider in a broad-brush way the motivations and key factors affecting three main actors in the process whereby private-sector agricultural innovations are developed and disseminated: farmers, private seed technology developers, and donors. African farmers face significant needs for seeds that address a multitude of agricultural production constraints – in particular, varieties that enhance yields and minimize yield variability in an environmentally sustainable

[3] Currently, there is also substantial discussion within the donor community regarding applications of AGPMs to a variety of non-seed based technologies as well. For example, a concept note describing a Canadian-sponsored initiative to promote AGPMs includes a large list of potential innovations – environmentally friendly fertilizers, crop management techniques, post-harvest technologies, livestock vaccines, instruments for reducing price volatility, and nutritional supplements (World Bank 2011). The focus here on an AGPM for seed-based technologies (in particular, seeds of open-pollinated varieties) is motivated by the fact that the sources of market failure for these technologies are well-known, and the candidate mechanism for ameliorating this market failure – adoption-based royalties – has garnered significant interest within the donor community.

way. The great majority of African farmers have small landholdings and operate under liquidity and credit constraints that limit their ability to purchase inputs (including seeds and fertilizers). Moreover, a host of transactions costs related to inadequacies in infrastructure, marketing systems, and institutions limit farmers' abilities to access inputs in a timely manner, as well as constraining their options for selling their output.

Private seed technology providers in Africa, both existing and prospective, face the same inadequacies in infrastructure, marketing systems, and institutions that farmers do. In addition, substantial agro-ecological variability, small country size and lack of integrated regional markets pose additional limitations on potential market size for specific varieties in the African context (Naseem, Omamo, and Spielman 2006). Finally, and of most interest to the current analysis, private seed companies in Africa face significant obstacles to recovering the substantial R&D costs associated with developing new seed varieties. On the one hand, liquidity and credit constraints on potential customers put a damper on sales of hybrid seeds that must be purchased annually in order to maintain yield gains. On the other hand, farmers' ability to save the seeds of open-pollinated varieties or acquire them from neighbors also limits the size of markets for those varieties. This is the case even in countries with plant variety rights laws, since the cost of enforcement for smallholder farmers is prohibitive relative to the benefits.

Donors have an interest in promoting the development and subsequent widespread diffusion of improved seed varieties. Throughout the developing world, and particularly in Africa, the great bulk of donor investments in the agricultural sector historically have been channeled through public institutions – international research centers affiliated with the CGIAR, regional organizations like CORAF and ASARECA, and national agricultural research systems (NARS).[4] And the great bulk of those investments may be characterized as "push mechanisms" aimed at increasing the supply of R&D (Elliott and Hoffman 2010).

However, growing impatience over the pace of agricultural development in Africa – and in particular, the apparent inability of traditional public-sector, push-based investment paradigms to successfully resolve the sorts of market failures noted above – have created significant interest in pursuing approaches that attempt to promote the involvement of the private sector in the process of innovation. These "pull mechanism" approaches center on offering financial incentives – prizes or royalty payments – to private firms in order to stimulate agricultural R&D and subsequent diffusion of the

[4] As of 2000, the most recent date for which comprehensive data is available, private investment comprised only 2.3 percent of total R&D spending in sub-Saharan Africa, with South Africa accounting for approximately two-thirds of all private R&D (Bientema and Stads 2006).

fruits of that R&D. The questions of interest here are (a) how such a program might work; (b) under what circumstances might it be most likely to succeed in promoting agricultural development goals; and (c) what might be some potential pitfalls.

Conceptualizing an Adoption-Based Royalty System

Figure 1 depicts the situation facing an hypothetical firm considering investing in the development and marketing of a new seed variety. Developing a new seed variety involves significant investments made over a period of time. In the figure, the size of this investment is depicted as the shaded area to the left of t* - that is, the (present) cumulative value the period of negative cash flow occurring between the time that work begins on developing the variety (t_o) and the time that the variety is released (t*).

As depicted in Figure 1, revenues from seed sales (net of seed production, marketing and distribution costs) begin to accrue at t* and continue to accumulate until the new variety is supplanted by a successor variety (e.g., up to).[5] The size of these cumulative net revenues will depend on the geographic area over which the new variety is agronomically suited; the new variety's superiority *vis-à-vis* existing varieties (in terms of yield, yield stability, pest resistance, etc); and the amount of time before the new variety is supplanted by an even newer one (i.e., – t*).

The benchmark time path for these net revenues is an s-shaped varietal diffusion curve. But the magnitude of the positive cash flow that follows dissemination of the new seed variety depends critically on how farmers procure new seed. For (non-reusable) hybrid seeds that must be purchased annually, the firm will gain net revenues from each kilogram of seed planted. In the figure, this amounts to the entire shaded area to the right of t*. If the resulting present value of (expected) net revenues exceeds development costs by enough to ensure a desired level of profitability, then the firm will go ahead and engage in the R&D activities needed to develop the new variety.

In contrast, for open-pollinated varieties (OPVs) the fraction of total area planted with purchased (certified) seed is quite low, especially among smallholders.[6] Hence, the cumulative net returns to the firm are only a fraction of those for annually-

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[5] To simplify the exposition, Figure 1 depicts varietal replacement as occurring all at once (at). In fact, replacement generally occurs over a period of time in much the same way as does diffusion (Heisey and Brennan 1991).

[6] Maredia, et al. (1999) indicate that only about 10% of total area of cereal and legumes grown by smallholders in Africa is planted with certified commercial seed. They estimate that saved seed accounts for roughly 60-70% of cropped area, while the remaining 20-30% is planted with seed that is borrowed or purchased in local grain markets.

purchased seeds; in Figure 1, this is depicted as the more darkly shaded area below the dashed line. If the seed purchases are sufficiently small – i.e., if self-provisioning of seed is a widespread phenomenon – then it will not be worth the firm's while to invest in developing the new variety, given that it does not expect to recover its R&D costs. This is, of course, precisely the situation that has limited the development of a private seed industry for OPVs in Africa.

An adoption-based royalty scheme represents an approach to insuring that returns to R&D are sufficiently large to entice prospective private seed firms to develop and distribute new varieties. Under such a scheme, an outside donor would guarantee royalty payments of $X for every hectare planted to a new improved variety over some pre-specified period of time. Now firms' assessment of the net returns from dissemination of the new variety will include projected royalty payments in addition to net revenues from seed sales. This is shown as the dotted line in Figure 1. The donor's goal in offering these ABRs would be to boost firms' total expected returns above expected returns from seed sales such that the area under this new net revenue curve would exceed R&D costs plus some minimum profit level required by prospective seed firms. Achieving that goal would effectively incentivize firms to develop new seed varieties.

The simplicity of this conceptualization belies a number of challenging implementation issues related to assessing likely diffusion patterns, the extent of farmers' seed self-provisioning, and R&D costs. To begin with, assume that R&D costs are known with reasonable certainty by the donor. The problem facing the donor would be to determine the resources needed to augment seed firms' revenues (from retail sales) by enough to more than cover R&D costs. Such a determination would require projection of the likely shape of the diffusion curve, as well its location (i.e., the timing of initial release). Specifically, establishing an ABR program would require the donor to set two parameters: the per-hectare payment (X) and the time frame over which the ABR payments would be made.[7]

To clarify this, consider Figure 2 which depicts a hypothetical varietal diffusion curve (the solid line) and associated ABR payments (the bars). For each year, the ABR payments are simply the area planted multiplied by a (constant) per-hectare payment

[7] Formally, define the present value of R&D costs incurred between t_o and t^* be $C =$, where R_t is annual R&D expenditures and β is a discount rate. Let A_t be the area planted of the new variety in year t (in ha), s be the seeding rate (in kg/ha), and θ be the fraction of land planted in purchased seed. The donor's problem is to choose the per hectare payment (X) and termination date ( ) such that , where M = is the present value of projected seed sales at (retail) seed price P_t.

("X"). Note that discounting effectively lowers the present value of future payments; hence the gap between the diffusion curve and the payout amount will diverge to some extent over time, the extent of the divergence depending on the size of the discount rate.

The choice of X and the payout period (arbitrarily depicted as ten years in Figure 2) are not independent of one another: A longer payout period would mean lower X, and a shorter payout period would mean a larger X. Additionally, note that lags associated with breeding and/or other product development activities would require a larger X, since the actual payout period would be shifted further into the future. On the other hand, more rapid adoption (i.e., a steeper diffusion curve) or a larger geographical area of suitability for the new variety (i.e., a higher adoption ceiling) would allow the donor to set a smaller X.

It is clear, then, that projection of diffusion paths would be essential to designing an ABR program that is efficient in the sense that the donor would end up exactly covering R&D costs. Underestimating either the ultimate adoption plateau or the speed at which diffusion reaches that plateau would lead to the donor "over-paying" – not a bad result from the perspective of ABR recipients, but one that would limit the donor's ability to honor its commitment (if the donor's budget constraint were binding) and/ or compromise its ability to offer ABR programs in other locations.[8] As well, such over-paying would likely lead to rent seeking behavior on the part of potential program participants for whom ABR payments would more than cover R&D costs.

On the other hand, an overly optimistic *ex ante* assessment of adoption would mean that actual payouts would not cover the seed company's R&D costs. Likewise, under-estimating the time it takes to bring a new seed variety to market would cause the present value of ABR payments to fall below R&D costs. Finally, if the *ex ante* adoption projections of the donor (the speed and/or the "ceiling" of prospective diffusion) were to be substantially more optimistic than those of seed company, then X would be set too low to fully cover the seed company's R&D costs. In all of these cases, such under-shooting could cause a potential program participant to simply refrain from developing a new variety (or to abort seed development activities mid-stream).

Finally, it is useful to contrast the mechanism for establishing royalty payments laid out above with the payment mechanism suggested by Masters and Delbecq (2008). They suggest a scheme in which compensation for a particular innovation developed by a given firm is based on that innovation's share of the total welfare gains created by <u>all</u> new technologies disseminated within a particular geographic region (presumably over some pre-specified time period). These "prize shares" would be computed on the basis

[8] I assume here (and throughout this paper) that donors face limitations on investible funds.

of *ex post* observation of the impacts of the set of technologies disseminated within the region. The shares would then be applied to a pre-committed pool of prize money made available by a donor organization to come up with each innovator's royalty payment.

The Masters and Debecq payment scheme is appealing in that (a) it is explicitly linked to actual social welfare gains; and (b) it is equitable in that it rewards beneficiaries in proportion to their contribution to those welfare gains. However, there are two aspects of Masters and Delbecq approach that render it less desirable than the approach that has been laid out here. First, by connecting individual firms' compensation to the performance of other firms' innovations, it would engender significantly more uncertainty among prospective seed firms as to the likelihood that royalty payments would cover their R&D costs. Accentuating this problem is the fact that information on relative successes of other technology developers in a region would only become available over time, thus adding another level of uncertainty to firms' assessment of whether of not it is desirable to invest in requisite R&D activities needed to develop a new product.

A second problem with the Masters and Delbecq approach is that it provides no guidance to donors as to the amount of resources needed to implement a system; rather, it assumes that donors come to the process with a specific amount of money to be committed. However, if the goal is to counter a specific market failure – i.e., the inability to recover R&D costs – then it seems more sensible that the pool of money be put up by donors be connected as directly as possible to a best assessment of what those R&D costs are likely to be on a product by product basis.

Information needs

The simple depiction of the problem laid out above illuminates the information needed in order to design and then implement a successful[9] adoption-based royalty system. These information needs are discussed below. At the outset, it is worth pointing out that the *ex ante* nature of such design considerations, coupled with the fact that we are dealing with a hitherto untested approach, brings considerable uncertainty to the program design process. With this caveat in mind, the discussion below is oriented toward ascertaining practicable means of minimizing the inevitable measurement errors associated with initiating an ABR system.

[9] Here, "success" will be taken to mean the scheme facilitates the development and uptake of varieties that would not have occurred absent the scheme.

R&D costs

Given that the primary goal of an adoption-based royalty system would be to cover the R&D costs associated with the development of improved varieties, information on those R&D costs is a fundamental information need for designing an ABR system. Generally speaking, two key elements underlie the difficulty, and hence cost, of varietal development: (a) factors related to the particular agronomic constraints that the new variety is meant to address or overcome; and (b) the extent to which existing (intermediate) advances in breeding can be exploited by prospective participating seed firms.

Regarding agronomic constraints, in many cases a natural tension exists between the geographic scale over which those constraints limit agricultural productivity enhancement and the cost of breeding efforts to overcome those constraints. Drought tolerance is an example of a trait that is notoriously difficult to attain through breeding. Some successes have been achieved, for example by the Drought Tolerant Maize for Africa (DTMA) program of CIMMYT and IITA, but these have come after large investments of financial and human resources by those centers and their NARS counterparts over at least ten years (La Rovere, et al. 2010). The key point here is that in general the larger the problem, the more expensive and more time-consuming will be the cost of finding a solution – but also the bigger the social payoff to that solution.

The extent to which existing (intermediate) advances in breeding can be exploited by prospective participating seed firms represents another critical element in gauging the size of firms' R&D costs – and, ultimately, in projecting the likelihood of success (or lack thereof) of a potential ABR system. It seems obvious that such a system will be more successful – and that those successes will unfold much more rapidly – if the private firm is able to piggyback on pre-existing breeding work undertaken by international or domestic agricultural research institutions. The model here would be one in which a local, private firm would engage in adaptive (finishing) breeding that tailors intermediate improved germplasm developed by public entities (e.g., a NARI or a CGIAR center) to local conditions – a "finish and deliver" approach (Traxler 2010).

Finally, it is important to note that information on private sector R&D costs is proprietary, and hence notoriously difficult to come by. The paucity of private seed research activities in Africa further complicate the process of arriving at reasonable R&D cost estimates (Beintema and Stads 2006). For this reason, a significant degree of information exchange between funders of an adoption-based royalty system and potential program participants would appear desirable early on in the process of designing the system in order to facilitate setting per-hectare payments. One worry in such situations is that potential beneficiaries would have an incentive to overstate their

R&D costs (and hence the ultimate per-hectare royalty levels). On the other hand, if such "conversations" were to take place when program funders (i.e., donors) are deciding whether and where to implement an ABR system, potential beneficiaries would have a stronger incentive to provide accurate cost information.

Other Demand and Supply Parameters

Information on seed supply and demand elasticities would not be needed to determine per-hectare royalty payments under an adoption-based royalty system. However, knowledge of these elasticities would be required for assessing welfare gains to participants in seed markets, however. Conventional wisdom suggests that seed supply is generally fairly elastic, while seed demand is fairly inelastic (MacRobert 2009); but specific elasticities no doubt vary (perhaps widely) by crop and from one location to the next.

Ex ante projections of surplus in commodity markets emanating from technology-led supply shifts would be valuable in helping donors decide which locations and which crops should be targeted by an ABR system. At the risk of stating the obvious, potential social welfare increases generally will be largest for crops and locations in which quantities supplied and consumed are greatest.

Finally, there would be a need to project likely retail demand for certified seed. Such a projection could simply assume some sort of rule-of-thumb regarding the frequency with which purchase seed *vis-à-vis* planting saved seed (Heisey and Brennan 1991). Note, however, that the seed:grain price ratio is an important component of demand for seed from retail seed dealers. If this ratio is high, then farmers would require larger yield increases from new varieties to justify paying the higher seed price (MacRobert 2009). On the other hand, if grain prices are very low (high) this tends to shift in (out) derived demand for improved seed acquired from retail outlets. The general presumption is that most farmers acquire OPV seeds from other farmers (or themselves) at prices close to the cost of grain, especially in relatively isolated areas (Smale, Diakite, and Drum 2010).

Ex ante Diffusion Forecasts

As previously noted, projection of the diffusion path of the new technology is another critical piece of information required to establish a per-hectare payment. A certain degree of imprecision is unavoidable in making such *ex ante* forecasts of the speed and extent of uptake of a specific variety. That said, several general tendencies have been widely observed:

- For a given area, diffusion will be more rapid the more experience farmers have with new varieties. This is particularly true for new varieties of the same commodity. But substantial evidence suggests that farmers with experience adopting modern varieties of one crop will be more likely to adopt modern varieties of a different crop.

- The overall scale of adoption of an improved crop variety will be correlated with the area planted to that crop. It is reasonable to expect, for example, that the total area of uptake for an improved variety of a staple food or major cash crop would be higher than that of more minor crops.

- To the extent that farmer-to-farmer exchange is expected to be an important conduit for the spread of a new variety, diffusion will be more rapid in places that are more densely populated, as well as in places with better developed transportation links, communication infrastructure, and social networks. All of these have been shown to facilitate seed transfer. Frequently, proximity to important urban centers will be related to these features of a particular rural region (Renkow 2007).

- The greater the extent of a pre-existing network of private seed dealers, the more rapid will be the spread of new varieties, due to greater ease of access by a larger number of farmers. On a related note, economies of scope in seed supply chains render it incrementally more profitable for retailers and distributors to deal in new product lines. For example, Tripp and Pal (2001) found that the rapid growth of the private rice seed industry in Andhra Pradesh in the 1990s was greatly facilitated by the relatively large number of pre-existing seed companies. In the current African context, these efficiencies would be confined primarily to locations in which private maize dealers currently exist, as maize seed is practically the only commercial seed widely sold on the continent (Byerlee 2010).

It is worth noting that these various tendencies are correlated. That is, more densely populated areas tend to have better infrastructure, and be more dynamic with respect to agricultural innovation. The other side of this coin, however, is that adoption of new varieties tends to be slower and less widespread in sparsely populated, more poorly "connected" locations. That these latter regions are often also areas of poor agronomic potential highlights a long-standing conundrum regarding the allocation of research resources between "more favored" and "less favored" areas of developing countries.

Monitoring Adoption Levels

End-point royalty systems that exist in other parts of the world – e.g., in Australia (GRDC) – pay seed developers for every ton of grain sold by farmers via a levy charged at the point of sale. This makes sense when farmers are commercial producers selling virtually all of their output. However, in Africa, a large fraction of production is for home consumption, and markets for many commodities (especially food crops) are widely dispersed and difficult to monitor. Hence, in the African context basing royalty payments on the level of adoption makes more sense. Expert assessments, field surveys, cell phone surveys are means by which information on adoption levels can be elicited. Recent advances in methods for DNA "fingerprinting" would appear to hold significant potential as check on these methods (Warburton, et al. 2010).

One point worth noting in regard to monitoring adoption is that seed developers standing to benefit from an ABR program will have strong incentives to ensure that the agency paying the royalties is fully apprised of adoption levels of their products. This provides a natural safeguard against under-estimation of total adoption. Consequently, there would be considerable value in having program beneficiaries take an active role in assembling adoption data upon which royalty payments are based, as suggested by Masters and Delbecq (2008). Of course, program beneficiaries stand to benefit from over-estimates, so external verification of these adoption data would still be necessary, using some combination of the assessment methods described above.

Potential Pitfalls and Other Issues

We turn now to other issues affecting the likelihood for an adoption-based royalty system to successfully promote the uptake of productivity enhancing technologies in Africa. Doing so requires some understanding of the fundamental nature of seed markets in the region – how well they operate and the institutional and other forces constraining participants – as well as a few subsidiary issues related to program design and implementation.

Seed markets

Seed markets are complicated systems with many actors. Tripp (2001) notes that the process of providing seed to farmers entails a chain of interlinked operations: (1) plant breeding; (2) source seed production; (3) seed multiplication; (4) quality control; (5) conditioning and storage; and (6) marketing (see Figure 3). Each of these links in the seed supply chain are indispensable for insuring sustained improvements from varietal development. In most parts of Africa, private firms are largely absent, and public sector entities have dominated each of these links in the supply chain. However, in the context of emerging, private seed systems, different firms may occupy these various links.

Inability to recover R&D costs – the primary constraint that adoption-based royalties would resolve – certainly plays an important role in limiting market-led development and deployment of improved seed. But it is only one of many constraints that must be addressed in order for ABR's to have a profound positive impact on agricultural productivity via stimulating private sector involvement in seed production and marketing. Stated another way, the viability of private seed markets in Africa are subject to a host of constraints – related to seed production and marketing; phytosanitary and trade policies; and farm-level seed demand – that are unlikely to be affected by an ABR scheme.

Langyintuo, et al. (2010) report the results of a 2007 survey of over 117 maize seed providers in East and Southern Africa – including more than 90 percent of all registered private seed companies in the region – to elicit information on key bottlenecks affecting the maize seed value chain in the region. Table 1 presents respondents' rankings of importance of various bottlenecks. Key constraints (and their rankings) that <u>would not</u> likely be impacted by instituting an ABR system include:

- Expensive production equipment (1)
- Access to germplasm (2)
- Trade restrictions (3)
- Lack of production credit (7)
- Retail distribution problems (8)
- Lack of qualified human resources (9)
- Poor infrastructure (12)

In addition, some constraints are only partially addressed. For example, the fourth-ranked constraint – low use of improved material on farm – will only be affected by an ABR program if royalty payments promote the development of superior varieties (from farmers' perspective). Likewise, the lack of operational credit might be partially resolved by an ABR program if firms' participation in the program makes them more credit-worthy from the perspective of potential lenders. However, this assumes that firms' prior inability to borrow is related to lenders' assessment that private seed firms wouldn't have been able to recoup R&D expenses (and, of course, that this inability to recoup R&D expenses would be perceived by lenders as being ameliorated by the availability of ABRs).

Seed policies relating to varietal release, seed certification, trade, intellectual property protection and GMOs, are a major constraint on private seed markets in most African countries. In general, these policies are either rigid and outdated, or they are nonexistent (Byerlee 2010). Seed policies are also country specific; several authors have pointed to the desirability of regional (i.e., cross-country) coordination of seed certification and testing procedures and raise transactions costs and fragment markets for private seed business (Tripp and Rohrbach 2001; Byerlee 2010).

The bottom line here is that adoption-based royalties cannot be realistically considered a "silver bullet" that will fix all problems related to seed system bottlenecks. Put another way, ABR's might be a necessary condition to making seed systems more viable, but in no way can they be considered sufficient.

Varietal Replacement Breeding

Successive replacement of varieties as they experience declining productivity – either through erosion of genetic improvements or as a result of some sort of disease, blight, or fungus – is an important element of the overall benefit of crop breeding (Marasas, Smale, and Singh 2003).[10] In the event that a limited number of seed companies compete in a particular geographic area, an ABR system could have the negative consequence of disincentivizing crop maintenance breeding.

To see this, consider the case in which only there is only one firm operating in a given geographic location. Replacement of one variety by another would yield no change in ABR payments to the seed company, assuming the same per-hectare payment for each variety. In this case, the firm would have less incentive to engage in maintenance breeding beyond the profits earned by sales of a newer variety – at least, up to the point at which yield erosion erases the yield superiority of the firm's improved variety *vis-à-vis* alternative varieties available to the farmer (e.g., landraces). Of course, if there were sufficient competition among multiple firms within a geographic area, then this issue would be less of a concern. In that case the potential loss of market share would restore the incentives of individual firms to engage in maintenance breeding. The take-away message here is that the degree of competition in

[10] For example, Byerlee and Moya (1995) found that wheat yield gains from maintenance breeding slightly exceeded yield gains due to improvements in genetic potential of successive varietal releases during the post-Green Revolution period.

seed markets matters to an ABR program's ultimate impact on aggregate yield growth within the location in which the program operates.

If in fact there is only one seed firm operating in an area, might there be a way in which an ABR scheme could be structured to maintain the incentive for the firm to engage in maintenance breeding? One possibility would be to tie ABR payments to some benchmark level of yields that must be maintained (presumably a level above yields achieved prior to adoption of the new variety).[11] This might restore the incentive of the firm to engage in maintenance breeding, but does raise an issue of identifying what average yields are in a particular location at a particular point in time (with all of the difficulties related to factoring in inter-annual variability in growing conditions, supply of complementary inputs, and the like). These are certainly surmountable problems – e.g. randomized trials or quasi-experimental (matching) methods can be used to compare outcomes with and without breeding for pest protection. However, doing so would raise program costs.

Another possibility would be to impose a limit on the number of years in which ABRs would be paid. Ideally, such a time limit would be based on knowledge of yield erosion that is likely to occur over time and/or some sense of the timing with which replacement varieties are likely to be developed. For example, MacRobert (2009) notes that yields of farmer-saved OPV maize typically are about 5 percent lower than yields of fresh seed of the same variety; by way of comparison, yield declines of about one-third are typical for saved hybrid seeds. But rule-of-thumb calculations such as those cannot account for diseases, blights, and other unforeseen stresses that might occur in particular locations at a given time.

Over What Time Period Should Royalties Be Paid?

As conceptualized, the rate for per-hectare royalties would be based on the size of R&D costs being covered, projection of the timing and extent of diffusion, and the length of time over which royalties will be paid. Specifying an appropriate period over which royalties are paid would depend on the time it takes to bring a seed product to market and the speed of adoption. These in turn are likely to vary widely, depending on the crop involved, the difficulties in accomplishing breeding objectives (including, of course, the availability of intermediate germplasm), as well as a host of factors affecting farmers' propensity to adopt new varieties within a targeted geographical region. The key point here is that it is important choice that merits considerable attention:

[11] Of course, another reason for linking royalty payments to some minimum level of yield enhancement *vis-à-vis* earlier varieties would be to avoid paying for "improved" varieties that no longer represent an "improvement."

Specifying too short a payout period (from a seed firm's perspective) would mean that expected total royalty payments would not cover R&D costs; whereas too long a payout period could be highly expensive to donors.

Note that the issue of how long royalty payments should be made raises a deeper question regarding the fundamental motivation for implementing of an agricultural pull mechanism like an adoption-based royalty scheme. If the idea is to provide subsidies to jump-start private sector participation in the seed industry, then it would seem desirable that an ABR program be as short lived as possible. That is, an ABR program could be designed to compensate "first movers" for the risks that they would take in entering a market by providing sufficient subsidies to draw a few private firms into the industry, then removing those subsidies once some sort of critical threshold of privatization were achieved. Of course, there is little guidance as what such a threshold might be. But the alternative, it would seem, is to subsidize private firms without an "exit strategy." Such an alternative would in all likelihood be undesirable from the perspective of donors, as well as being potentially questionable on the grounds of social efficiency.

To Whom Should Royalty Payments Be Made?

Virtually all countries in Africa now have plant variety rights (PVR) laws to insure the distinctness, uniqueness, and stability of specific varieties and to confer property rights over those varieties. As such, it should generally not be difficult to direct royalty payments the appropriate "owner" of specific seed varieties. In cases in which a variety registered by a private firm, then that firm would receive the payments. In cases in which a variety is registered by national agricultural research institute (NARI) but is marketed by a private firm under a non-exclusive license, royalty payments would still be paid to the NARI. It would then be up to the two parties to negotiate a split of the royalties in accordance with their contribution to the total net revenues generated. In this way, royalty payments would be distributed throughout the seed supply chain (Kremer and Zwane 2005).

But while the ubiquitousness of PVRs mitigates difficulties of identifying the appropriate recipient of royalty payments, a more difficult problem is verification of which varieties are being grown in particular locations. As noted earlier, there are a number of possible means of assessing how much of particular varieties are being grown in a particular area – expert assessments, field surveys, cell phone surveys, DNA fingerprinting. However, the accuracy and the cost of these various assessment methods is likely to be variable across locations.

The widespread nature of mixed cropping in Africa raises an additional issue related to royalty payments. Output per unit of land for a particular crop will differ between mixed- and sole-cropped plots. Thus, to the extent that yield enhancement is the dominant improvement associated with a new variety, it is by no means clear that royalty payments for a hectare of sole-cropped land should be the same as for a hectare that is of mixed-cropped land. On the other hand, to the extent that the major goal of an ABR program is to stimulate privatization of the seed system, this would be of lesser concern.

Financing Issues

The process of breeding for genetic gains, subsequent commercial distribution of improved seed, and ultimate uptake of that seed takes place over a period of years. Initial investments in these activities don't see payoffs until the later stages of that process. Clearly, there is an essential need for credit to bridge this gap in timing between investment and returns – a need faced by any entity (public or private) in the seed development business.

Recall that poor access to credit is an important constraint on private seed firms (Langyintuo 2010). This begs the question of how this might impact the prospects for success of an adoption-based royalty system (or any privatization of seed, for that matter); or, alternatively, where and in what circumstances might credit constraints not be binding to the point of precluding privatization of the seed system?

It is first important to recognize that that the need to finance activities occurring prior to point in time when seed sales and royalty payments generate positive cash flow will not be resolved by an adoption-based royalty system. The returns to participants in an ABR program may be computed differently than in "normal" private markets, but they do not change the basic gap between investment and payoff.

Three additional observations are noteworthy in this regard. First, the potency of these financing issues will be greater the longer the period of time required for product development. For example, a firm developing a variety that adapts intermediate germplasm to local conditions – a "finish and deliver" research and marketing effort – would be less affected by credit constraints than if the firm were to engage in more basic breeding work. Second, it seems likely that larger seed firms – particularly, multinational firms that operate in a number of countries worldwide – would have more ready access to the necessary lines of credit than smaller, domestic firms.

Third, places in which there is already a greater private sector presence in the seed marketing system would be more likely to possess more viable participants in an adoption-based royalty scheme. Significant economies of scope in private seed markets around the world means that in general the most successful seed firms deal in multiple crops and multiple varieties of the same crop (Tripp 2003). Facilitating positive cash flow is a powerful positive spin-off of this intra-firm diversification. As such, financing issues would tend to be less onerous – and less damaging to the prospects for program success – in locations and markets areas populated by pre-existing seed businesses.

Conclusion: Challenges and Prospects for Success

In this paper, I have laid out a number of issues regarding the mechanics of implementing an adoption-based royalty system for enhancing the role of the private sector seed in African seed markets. The analysis has highlighted a number of challenges that must be confronted in the design and implementation of ABRs. Chief among these challenges are the following:

- Projecting the cost of private sector R&D activities associated with bringing seed products to market;
- Assessing *ex ante* the likely rate and extent of dissemination of new seed varieties;
- Determining the length of time over which royalties would be paid;
- Monitoring adoption levels of seeds on which royalties would be paid;
- Addressing potential conflicting claims over attribution of improved varieties to specific institutions;
- Factoring in constraints on the functioning of seed markets that are relatively ubiquitous and unlikely to be affected by ABRs (or by any agricultural pull mechanism for that matter).

Given that an adoption-based royalty system has never been implemented, it is prudent to consider what features of a potential venue for such a system would maximize its prospects for success (as measured by dissemination of improved varieties). The foregoing discussion has highlighted a range of factors likely to maximize the potential for success of an adoption-based royalty system:

- *A shorter R&D period:* Taking intermediate germplasm and adapting it for local use ("finish and deliver") has a higher probability of success than developing a product requiring more basic breeding. It is also takes place over a more compressed time-frame, thereby lessening overall costs (including finance costs).

- *Geographical areas with better agronomic conditions:* It is easier to achieve successes in breeding (especially for yield increases) in favorable agro-ecological zones. Of course, some breeding efforts are explicitly target less-favored areas – drought tolerance breeding programs are a notable example; but this in no way changes the relative difficulty of achieving breakthroughs for difficult production environments. Particularly in the case of pilot projects aimed, at least in part, at ascertaining the viability of a novel approach, there is wisdom in "road-testing" an ABR system under less difficult breeding challenges.

- *Areas in which a private sector seed system already exists:* In Africa, this essentially means a private maize seed system. In most countries, such a private sector system is either non-existent or very poorly functioning. South Africa is the only country on the continent with what might be termed a "mature" private seed industry; countries with emerging private maize seed industries include Kenya, Zimbabwe, Zambia, Nigeria, and Ethiopia (Byerlee 2010).

- *Locations and crops for which area farmed is large and agronomically homogeneous:* Relative to the costs of breeding, potential payoffs to a specific breeding program are larger when the target crop is higher-valued and/or farmed over a larger area. All else equal, this gives an edge to targeting an ABR system toward staple foods over more minor food crops, and high-valued over low-valued cash crops.

Note that all of these factors support piloting an ABR system in locations that are "favored" along any of a number of dimensions – agro-ecology, infrastructure, human capital, institutions.

Two final points merit mention. First, the underlying – and often unstated – premise of advocates of private solutions to product development and marketing challenges in the seed sector is that the private sector is more efficient than the public sector at meeting these challenges. For this to be true for the plant breeding portion of the process, there should be compelling evidence that the private sector possesses a stock of knowledge that is unavailable to the public sector. This might be the case for some important crops grown in Africa – cotton and maize are examples. However, for many crops the largest repository of knowledge relevant to genetic improvement is the public sector, notably CGIAR centers. In these cases, the comparative advantage of the private sector is likely to rest primarily in adaptation, testing and delivery of final seed products.

Second, this paper has focused on one approach (an ABR system) to addressing one particular source of market failure – namely, the inability of private firms to recoup the value of R&D investments in seed breeding. But in passing, we have alluded a host of transactions costs affecting various links in the seed supply chain, as well as other significant sources of market failure affecting farmers' propensity to adopt new varieties. Thus, there can be little doubt that success of an ABR system will in many instances hinge critically on complementary investments in institutions, infrastructure, and other key elements of a well-functioning agricultural economy.

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Figure 1. Time Path of Costs and Returns to Seed Varietal Development

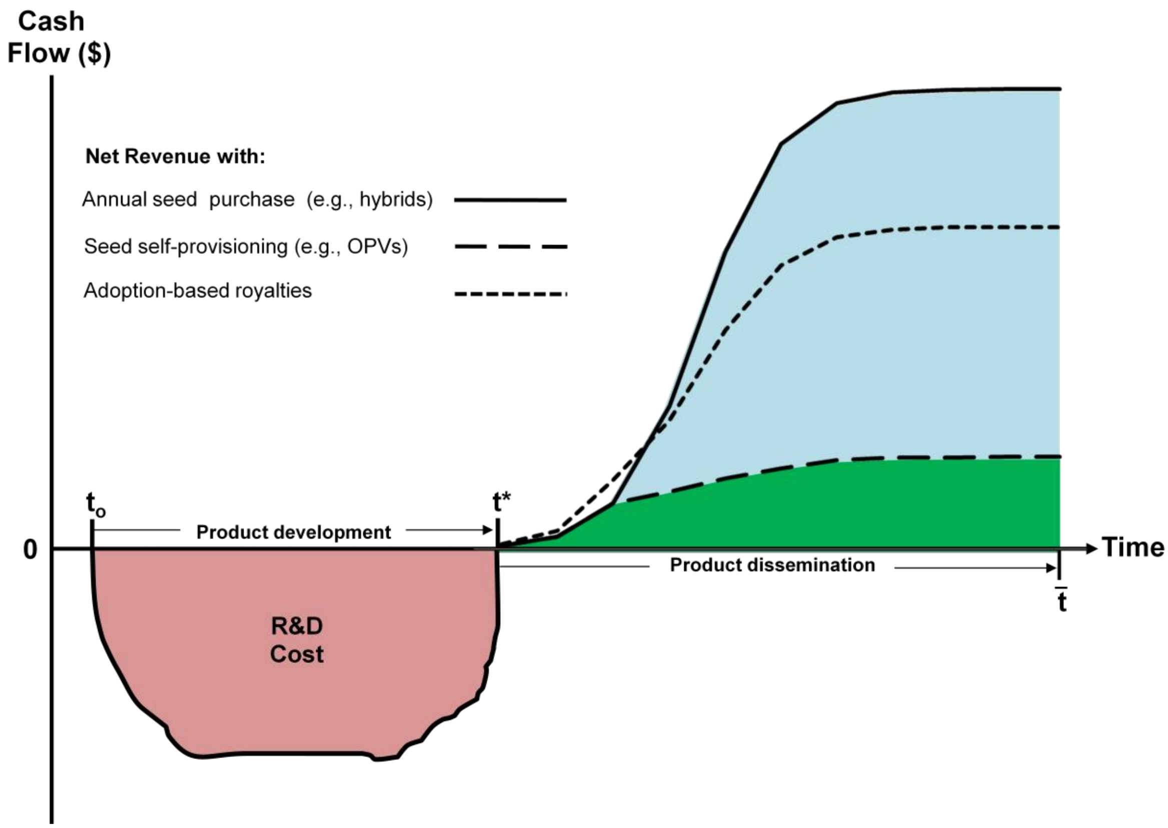


Figure 2. Diffusion and payout of ABRs

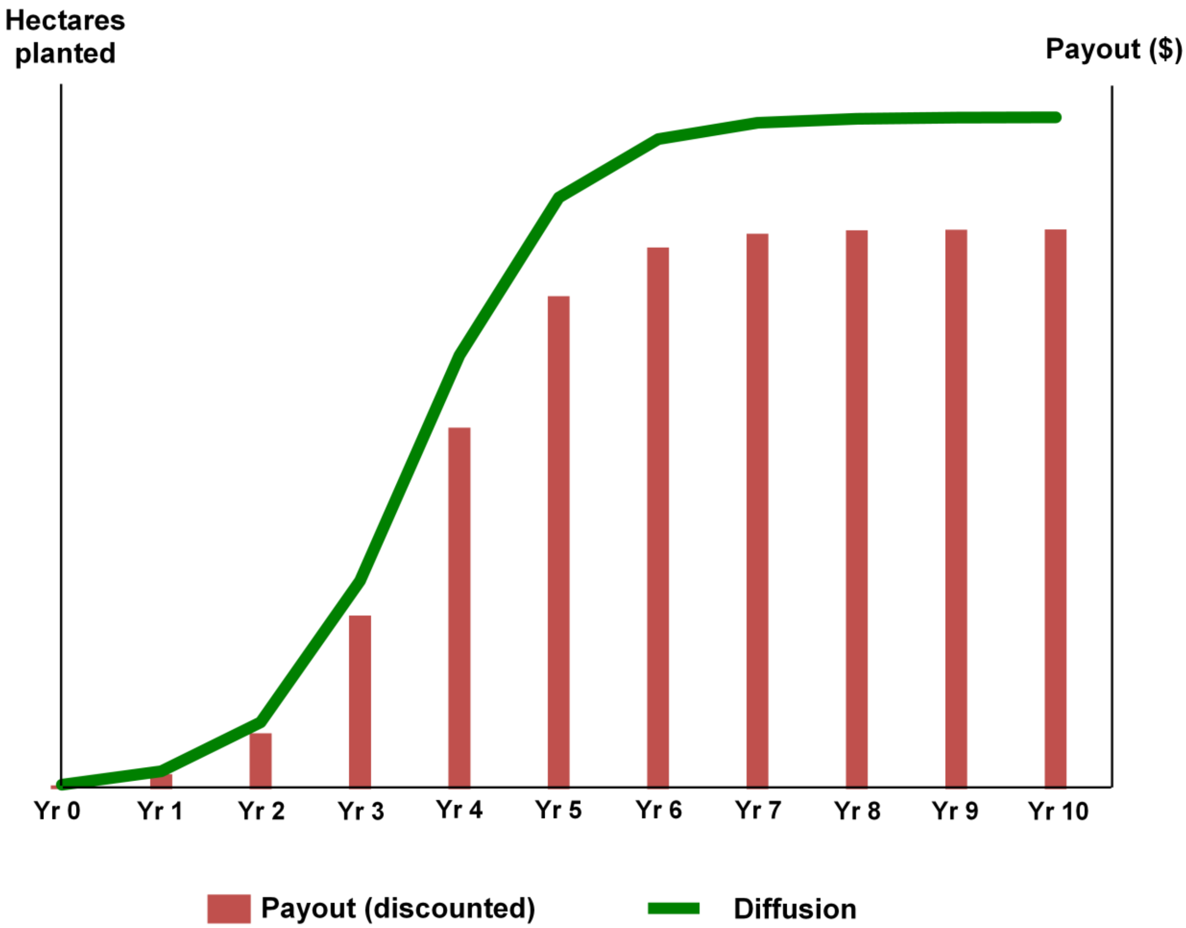
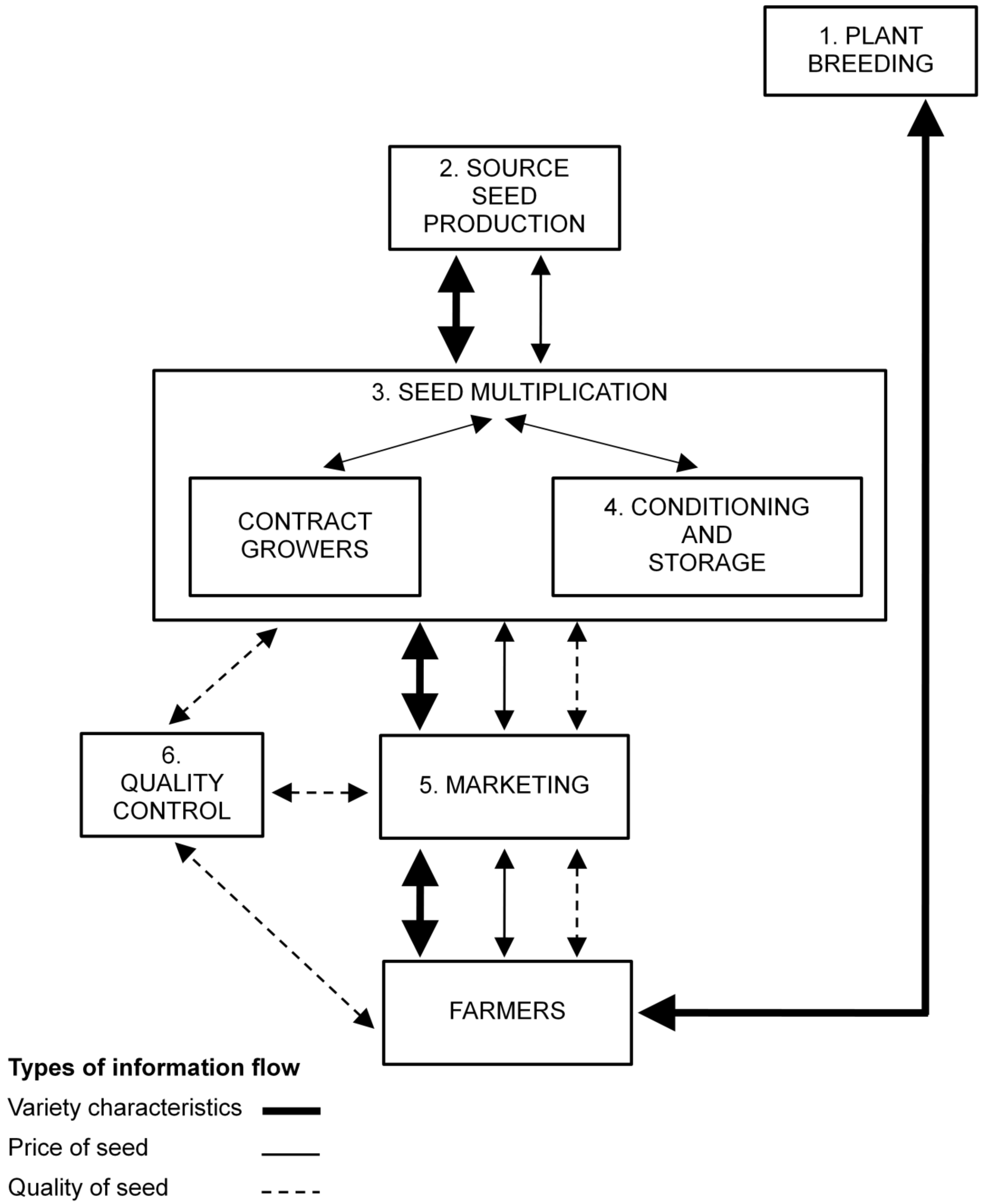


Figure 3. Links in the Seed Supply Chain



Source: Tripp (2001)

Table 1. Ranking of bottlenecks affecting establishment and efficient operation of seed companies in East and Southern Africa

Constraint	Rank	Ameliorated by an ABR System?
Production		
• Expensive prod'n equipment	1	No
• Access to germplasm	2	No
• Production credit	7	No
Seed Policy		
• Trade restrictions	3	No
• Lengthy varietal release	6	Maybe
Farm-level Demand		
• Low use of MVs on farm	4	Maybe
• Demand estimation	11	No
• Poor extension	13	No
Business Establishment		
• High investment cost	5	Yes
• Qualified human resources	9	No
• Operational credit	10	Maybe
Marketing		
• Distribution problems--retail	8	No
• Poor infrastructure	12	No

Source: Langyintuo et al., 2010