MEETING THE CHANGING NEED FOR HERBAGE SEED QUALITY ASSURANCE IN THE 21ST CENTURY

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Abstract

Quality assurance is a key element in the herbage seed supply chain. The measurement and management of seed quality is discussed in terms of its four main parameters - genetic, physical, vital, and phytosanitary quality - which provide information on the expected performance of herbage seed when sown in the field. During the past century, seed quality management systems have evolved in response to national and regional differences in economic development, crop characteristics, merit testing, and the demands of international trade. The pace of change in the management of seed quality assurance has intensified in developed countries over the past decade or so, driven mainly by the ability to protect intellectual property, the consolidation of seed companies into larger units, and government policy aimed at deregulating the delivery of quality assurance. In developed countries, this has seen the strong private seed sector taking increasing responsibility for seed quality assurance, both economically and legally, together with the emergence of private seed testing laboratories and in-house certification programs. However, developing countries without a strong private seed sector are better served by the more traditional model in which government takes on the role and responsibility for managing seed quality assurance in the public interest. This paper explores recent trends in seed quality management and their strategic implications for different countries now and in the future with particular reference to herbage seed.

Introduction

The successful establishment of a new pasture or amenity sward from seed depends in the first instance on sowing good quality seed[1]. The end user needs to know that the seed will produce an even stand of the stated cultivar without introducing unwanted weeds, diseases or other pests. The seed should also be capable of germinating, emerging, and establishing reliably and uniformly under normal field conditions at the recommended sowing rates. This requires appropriate measurements and assurance of quality in the market such that any particular seed lot offered for sale is described accurately.

Seed quality assurance is an integral part of an effective seed supply system. In this paper, we look first at what constitutes seed quality, how it is measured, and its specific application to herbage seed. Next, we examine differences between countries in their approach to quality assurance, analysing the underlying factors that collectively shape this. Finally, we discuss global

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[1] 'Seed' in the broad sense covers all planting material. While this paper focuses mainly on botanical seed, aspects of quality assurance are also applicable to vegetative propagating material.

changes taking place in the systems that deliver quality seed to end users, together with the driving forces behind these trends.

Seed Quality Parameters

Definition of seed quality

'Seed quality' is not a single attribute; instead, it comprises a number of discrete components, which are considered to be of importance for sowing purposes (e.g. Esbo, 1980). As defined by Thomson (1979), these include freedom from weed seeds, analytical purity, species purity, cultivar purity, germination capacity, vigour, size, uniformity, health and moisture content. Some are properties of the seed lot (its physical purity and homogeneity), while others are collective properties of the individual seeds (including their genetic identity, vitality, and freedom from disease).

Other authors (e.g. Hill *et al.,* 1997) vary in their treatment of the various attributes that collectively describe seed quality. However, for the purposes of this paper, we have grouped these into four main categories, each with a separate but complementary role in achieving the overall goal. These are:

- Genetic Purity, which ensures that the seed consists of the stated species and cultivar;
- Physical Purity, which measures the degree of contamination by weeds, insects and inert matter;
- Vital Quality, which covers seed viability, germination, and vigour; and
- Seed Health, which relates primarily to freedom from seed-borne diseases and pests (i.e. phytosanitary quality), but physiological conditions such as trace element deficiencies may also be involved.

Each seed lot should also be homogeneous with respect to these various components. The value of such measurements in a practical context declines as heterogeneity within the seed lot increases. Seed moisture content may be determined, but is not a measure of quality *per se*; rather, it affects the maintenance of vital quality in storage and perhaps seed health as well if it is too high.

Assessment methodologies

'Seed quality' can only be determined through proper assessment of the various quality parameters. It cannot be accurately evaluated through a cursory examination of the seed.

In the case of physical purity and vitality, testing must be carried out in a laboratory. Protocols for the analysis of purity, germination, viability and vigour of seed in seed samples have been standardised for most of the established herbage species by the International Seed Testing Association (ISTA) and the North American-based Association of Official Seed Analysts (AOSA). The 'Rules' for seed testing are now closely harmonised between the two organisations and are the only internationally recognised quality assessment methodologies for purity and germination parameters. They form the foundation on which seed quality management systems are developed, both for internal use within countries and for international trade.

Genetic quality assessment and management is generally organised through identity preservation systems (traditionally called 'seed certification' systems) where the varietal identity of a plant cultivar is monitored, as an evidentiary chain, from one plant generation to the next. The principles and practices for these systems are documented for application to most field crop, forage and vegetable species in the Rules and Directions of the Seed Schemes for the varietal certification of seed moving in international trade of the Organisation for Economic Cooperation and Development (OECD) (OECD, 2000). Schemes using similar principles and practices, mainly for the domestic market, have been set up by the Association of Official Seed Certifying Agencies (AOSCA), which is based in North America but has members also from Argentina, Australia and New Zealand (AOSCA, 1999a, 1999b).

Seed health (phytosanitary quality) relates primarily to two situations: seed moving into the country (import quarantine) and seed being exported (often referred to as export certification). Most countries have developed import quarantine protocols based on their individual ecological circumstances and regulate these in accordance with multi-lateral conventions such as those administered by the International Plant Protection Commission (IPPC) of the Food and Agriculture Organisation of the United Nations (FAO). Seed destined for export is generally subject to certification on the basis of phytosanitary conditions prescribed by the importing country.

In both of these scenarios, assessment of the phytosanitary status of the seed may need to be determined by analytical methods. Standardisation of appropriate methods for detection of many microorganisms has recently been undertaken by ISTA in collaboration with the international seed industry through the International Seed Health Initiatives (ISHIs) for vegetable, field crop and herbage species.

Application to herbage seed

National seed testing requirements and quality assurance (QA) systems have evolved mainly in response to the arable and horticultural sectors, rather than the much smaller markets for herbage seeds. This has mostly been serviced through general laboratories, with some smaller specialist laboratories in developing countries.

The basis of genetic quality management for herbage seeds is essentially the same as procedures used for arable and horticultural crops, although proportionately greater use is made of seed certification with temperate herbage seeds than for arable crops where much of the seed sown is farm-saved and, hence, uncertified. Seed crops are grown in isolation and their varietal identity verified and maintained through a system of crop inspections, labelling, and post-harvest verification. By and large, isolation distances used for herbage seed crops are based on rules developed for other crop plants that are pollinated similarly (by wind or insects) and the relatively few studies that have been conducted on herbage species (e.g. Hodgson, 1949; Griffiths, 1956; Bogdan, 1963) tend to validate current procedures. To date, post-harvest verification of genetic purity for different lots of certified seed has been based on morphological characteristics in small plot growout tests. However, as DNA profiles (or ‘fingerprints’) become available for individual cultivars in the future, increasing use will be made of DNA testing to give a more rapid result.

When testing for physical purity and vital quality, the same general principles apply to all agricultural seeds. Except for recently commercialised species, standardised testing conditions and procedures have been established internationally for individual species and the published ‘Rules’ (ISTA, 1999) are updated regularly.

In the case of herbage grasses where the seed unit does not always contain a caryopsis, there are two main approaches to the determination of physical purity. For seeds that flow freely and will separate easily in an air stream (e.g. *Brachiaria* spp., *Panicum* spp., *Dactylis glomerata*, *Poa pratensis*), a caryopsis must be present before the seed unit can be classed as a 'pure seed' - the so-called International Method. In the case of chaffy seeds that do not flow freely (e.g. *Andropogon, Cenchrus, Chloris* spp.), a less stringent definition is applied, classing seed units as 'pure seeds' provided they look as though they could contain a caryopsis - the so-called Irish Method. In such cases, the alternative is to determine manually whether or not a caryopsis is present, and is very time-consuming and expensive.

Determining the vital quality of herbage seed is often a much more complex issue than for arable and horticultural crop seeds because seed dormancy and/or hardseededness are often involved. Greater use is therefore made of viability (tetrazolium) tests in conjunction with germination testing to assess the vital quality of dormant grass seeds. Chemical additives and pretreatments to break dormancy/hardseededness are also used during germination testing. Information on the vigour of germination would be useful in predicting the likely performance of seedlings during establishment. However, unlike crop seeds, reliable vigour tests have yet to be devised for herbage seeds. Similarly, further work is required before accelerated aging techniques (e.g. Ellis and Roberts, 1981) could be used to predict the survival of herbage seeds in storage.

In the case of temperate herbage grasses and legumes, seed health testing relates particularly to economically important seed-borne pathogens. Such tests are essentially crop-specific, because they are determined by the diseases that afflict a particular species. For example, the main concern in temperate grasses is for blind-seed disease (*Gloeotinia granigena*) of *Lolium* spp. and *Festuca arundinacea* (which are especially susceptible), for ergot (*Claviceps purpurea*) on *Poa pratensis* and *Agrostis* spp., and stem rust (*Puccinia graminis*) on *Lolium* spp. (Rolston *et al*., 1997). Increasingly, attention is also being directed to determining the presence and viability of endophytic *Acremonium* fungi in certain *Lolium* and *Festuca* cultivars. In temperate legumes, the main concern is for bacterial wilt (*Corynebacterium insidiosum*) and verticillium wilt (*Verticillium albo-atrum*) carried on *Medicago sativa* seed; brief descriptions of the effects of these two diseases are provided by Marshall *et al.* (1997).

Health tests are not routinely conducted on tropical and subtropical herbage species although the incidence of ergot-infected seeds is determined on susceptible species such as *Paspalum dilatatum*. However, the possibility that diseases might be transported in or on the seed (e.g. smut diseases of many grasses, seed-borne viruses in *Vigna unguiculata*) is also dealt with through plant quarantine.

Factors Influencing Quality Assurance Strategies for Herbage Seed

At any one point in time, the needs and strategies for herbage seed quality assurance will differ between countries. In many cases, the use of improved forage varieties is not well developed; in others, forage seed markets for animal production have reached saturation point, and herbage seed production is gradually expanding into the growing amenity seed markets, which also tend to be more profitable. In all cases, however, the herbage seed sector tends to be swept along by decisions taken in the much larger markets for arable and horticultural seeds rather than being the direct focus of those decisions.

Stage of national development

A major factor in determining quality assurance needs and strategies in any country is its stage of development. National circumstances must be considered on a case-by-case basis. The development of a seed sector is a gradual process, and requires the progressive implementation of quality assurance and management procedures in parallel with this. Historically, this has been the scenario in developed countries. In many developing countries, however, governments introduce seed laws based on an advanced developed country model (Farrington and Witcombe, 1998). Often this is in response to, and with the well-meaning support of, donor aid agencies; but it usually involves moving rapidly from a very low level of seed quality assurance to impose a rigid bureaucratic system, rather than promoting the evolution of simpler, flexible arrangements more attuned to the evolving national needs. The risk is that an overly rigorous approach and the premature introduction of advanced aspects of quality assurance in a developing country may, in fact, stifle the very activity needed for its continued development with little or no positive effect on the quality of herbage seed in the marketplace.

In extreme cases, the first step in a developing country is simply to make herbage seed is available and, where possible, to ensure that this has been tested for purity and germination. Not infrequently, the alternative at such an early stage of development is that farmers wanting to use seeded species must propagate them vegetatively due to the unavailability of seed. Often, there is only one cultivar per species and hence no real need to implement a certification scheme, particularly if the species involved are apomictic or self-pollinating. Invariably, the trained human resources needed to run a more sophisticated seed quality management system are not available, even if the on-going financial burden could be met.

This is the point at which many pilot projects and government seed programs in developing countries must start (e.g. Hare, 1993). The first step is to ensure that seed is ‘truthfully labelled’ according to its purity and germination. Gradually, as herbage seed production develops and key staff are trained, other aspects of seed quality management can be added, first certification as the number of similar cultivars increases and later seed health as and when appropriate. This is a process of evolution in which a highly sophisticated QA system is simply not warranted during the early stages.

In countries with high population pressure, the priority is to produce food directly from plants rather than indirectly through animal product (milk, meat), except in areas where cropping is not possible. China, for example, has seen a good deal of research on forages and forage seeds over the past 15 years or so, but the application of those results at an operational level is still rudimentary at best. Amenity use of grasses (including roadsides) is perhaps developing more rapidly, driven by increasing urbanisation and the need to provide a more pleasant living environment.

India has developed a strong seed certification system for arable crops and annual fodder crops (Agrawal and Tunwar, 1990), but this has had no significant impact thus far on the much smaller market for seeds of perennial forages. In fact, as Turton and Baumann (1996) found, the need for forage seed domestically is being serviced mainly through the informal sector by a complex network of middlemen, merchants and traders, who provide links between seed collectors/producers and end users perhaps thousands of kilometres apart. All of this seed is uncertified and untested.

Seed certification strategies and needs

Pedigree vs. pure line certification. Seed certification schemes are designed primarily to maintain genetic integrity and to minimise the risk of physical contamination by seeds of other cultivars. In some cases, they are also implemented to ensure freedom from seed-borne diseases. There are two basic types of certification scheme.

- A pure line system is used with cultivars of highly self-pollinating species with little chance of variation from one generation to the next. It was developed to facilitate the certification of *Trifolium subterraneum* (sub clover) and annual *Medicago* spp. (medics), which are unique among the OECD Seed Certification Schemes (Boyce, 1990). Logically, a pure line system should also be used with apomictic species where asexual reproduction ensures that there is no variation from one generation to the next.
- A pedigree system limits the number of generations that a cultivar can be multiplied, thereby minimising the risk of genetic drift in cross-pollinating cultivars (e.g. *Chloris gayana*, *Dactylis glomerata*, *Lolium* and *Festuca* spp., *Medicago sativa*, *Trifolium* spp.).

AOSCA certification schemes for vegetative turfgrasses in the US and Australia are essentially based on the pure line model. Multiplication of these cultivars is again by asexual means.

Temperate vs. tropical. The use of certified seed is widespread and generally accepted in temperate countries, such that the need to certify is rarely questioned. For various reasons, however, certification has not been so universally or unequivocally accepted in the tropics (Loch, 1993). Firstly, the number of released cultivars from each commercially available species is far fewer than for the temperate zone; conversely, the number of forage species commercialised in the tropics is much greater.

Secondly, end users in the tropics tend not to place a high priority on cultivar uniformity and stability, and are reluctant to pay the extra cost of maintaining it. In part, this reflects the fact that there have been few critical studies to highlight the extent of genetic drift in susceptible tropical herbage cultivars (e.g. Imrie and Blogg, 1983; Hacker, 1987). However, it also reflects a widely held scientific opinion that variability and the capacity for cultivars to change may actually be useful adaptive attributes, particularly in pioneering situations. For this reason, physical mixtures are sometimes marketed (e.g. *Stylosanthes scabra* cv. Siran - a mixture of three individual cultivars) to provide greater resilience.

Another crucial difference with regard to certification of temperate and tropical herbage species is their predominant modes of reproductive behaviour. With the exception of *Poa pratensis*, the major temperate grasses and legumes are outbreeders (e.g. *Festuca* and *Lolium* spp., *Medicago sativa*, *Trifolium repens*) and therefore subject to genetic drift through uncontrolled multiplication (Fairey *et al.*, 1997). In contrast, the major tropical forage species tend either to be predominantly or wholly apomictic (e.g. most *Brachiaria* spp., *Cenchrus ciliaris*, *Panicum maximum*) or are strongly self-pollinating (most legumes) (Hacker and Hanson, 1999). In both cases, there is relatively little or no risk of genetic drift through uncontrolled multiplication. Among the tropical grasses, major exceptions showing outbreeding behaviour include *Andropogon gayanus*, *Chloris gayana*, *Digitaria* spp. and *Setaria sphacelata*.

In Australia, certification is widely used with temperate herbage seed in the southern States, but has only a very limited role in Queensland and the Northern Territory where the emphasis has been on releasing new species of tropical pasture plants rather than developing new cultivars of the current range of species. In the latter cases, certification tends to be offered only where there is a risk that cheap seed of an inferior cultivar will contaminate, or be substituted for, expensive seed of a desirable cultivar. A case in point was the certification of *Chloris gayana* cv. Callide to distinguish it from the older inferior but widely used cultivar ‘Pioneer’ (Loch and Friend, 1980), although market complacency has led to less certification of ‘Callide’ seed in recent years. By comparison, an earlier attempt to introduce a certification scheme for *Cenchrus* *ciliaris* (an apomict) in the late 1950s was a conspicuous failure through a lack of market support (Beavis and Harty, 1999).

Proprietary marketing

The presence or absence of intellectual property (IP) rights in different countries has far reaching effects on the delivery of herbage and other seeds to end users and on their perception of genetic, physical and vital quality. This can be seen in the contrasting descriptions of these two extremes by Loch (1997). Plant Breeders' Rights (PBR) - the main form of IP used here - is often described as the only independent form of intellectual property protection designed specifically for new plant cultivars, but as we discuss later, some other forms of IP can also be used to protect certain aspects of plant cultivars.

Where there is no recognition of any intellectual property rights embodied in new cultivars, they are publicly owned. Essentially, there is no control over their exploitation via seed because anyone is free to produce and sell this (Figure 1). The tendency is therefore to regard 'seed' as a commodity with little or no differentiation beyond the species level, and for transactions to be based on price, often with little or no regard for its physical quality and even less for its genetic quality. Margins are tight and price becomes a major consideration in sourcing seed - hence the often antagonistic and wary relationship between seed growers and the seed companies that buy their seed. In this cut-throat world preoccupied with price, the seed trade inevitably gives preference to lower-priced opportunists over reliable seed producers. This hinders the development of a more professional class of seed growers (and a more professional seed industry overall). Periodic shortages and surpluses occur, since no single participant in the industry is in a position of even attempting to link supply with likely demand in a rational way. This is exacerbated by producers opting in and out of the industry depending on seasonal conditions and the prices they can receive for seed relative to alternative commodities (e.g. grain, beef). Finally, seed companies are unwilling to promote public cultivars, both for fear that their competitors could also benefit from their investment and because margins are so narrow. Similarly, with no control over the end products, no one in private industry is willing to finance plant breeding, hence this remains a public sector responsibility.

Insert Figure 1 near here

The rationale for using intellectual property to develop an effective proprietary seed supply system is to transform 'seed' from a relatively undifferentiated low profile commodity into a range of proprietary products (cultivars) marketed actively by different companies and individuals. The key here is the exclusivity conferred by proprietary ownership of individual cultivars. Essentially, all stages in the production and marketing of seed can now be managed via the rights vested in the licensee (seed company) by the breeder (Figure 2).

Insert Figure 2 near here

With this security, seed companies are encouraged to invest in the development and promotion of new cultivars. Seed ceases to be a relatively undifferentiated commodity; instead, there is a range of proprietary products (cultivars) developed for different uses. As in any commercial situation, price remains a consideration, but no longer the over-riding issue that it is in a non-proprietary environment. Instead, user recognition of improved cultivars (through effective promotion of genetic quality) enables both seed company and seed grower to benefit through better prices for premium quality seed. In turn, this leads to stronger and mutually beneficial links throughout the production and distribution chain, and hence a more professional, informed and stable seed industry. Production can now be planned with greater confidence, thus helping to dampen some of the wilder swings in supply and their de-stabilising effect on price which can be seen in an uncontrolled non-proprietary industry. Growers have greater security (backed by contracts), while marketing opportunities for seed companies create greater awareness and knowledge of their various proprietary cultivars - they become ‘seedsmen’ rather than ‘salesmen’ with only superficial technical knowledge. This, in time, will reduce pressure on publicly funded extension services.

The effect of proprietary marketing also depends on the mix of cultivars involved. Because public cultivars are essentially commodities traded on price, large numbers of these will simply drag down any premium for genetic and physical quality that otherwise might be achieved with seed of proprietary cultivars.

Similarly, the substantial sales of seed labelled only as ‘Variety Not Stated’ (VNS) in the USA or as ‘Common’ seed in Canada have the effect of putting pressure on the seed price of proprietary herbage cultivars. For this reason, US herbage breeding programs include a strong emphasis on seed yield so that returns to both seed companies and to seed growers can be increased.

Merit testing of new cultivars

Throughout Europe, official testing is carried out on new forage and amenity cultivars to establish their Value for Cultivation and Use (VCU), which is the basis for their inclusion on the National and/or the Recommended List. Under European Union (EU) regulations, only cultivars on the National List of a member country or on the EU Common Catalogue can legally be sold there. Parallel to the VCU trials is the official testing of new cultivars prior to PBR registration to determine their Distinctness, Uniformity and Stability (DUS). It is only after a new cultivar meets both the DUS and VCU criteria that it can be commercialised.

In most other developed countries (e.g. USA, Canada, Australia, New Zealand), there is no provision for national listing through official VCU trials. These countries take the view that there is more to be lost by delaying commercialisation of an improved cultivar than by the release of an inferior/unimproved cultivar: the market is the final arbiter. Merit testing is conducted by the breeder/breeding agency, and the new cultivar has to meet the DUS criteria if proprietary protection is required by the breeder. This provides a more flexible system, enabling new cultivars to be released earlier to find their own commercial level. It is also more responsive to the changing needs of the particular country or region.

International trade

Seed storage. As international trade in herbage seed increases, so does the need to ensure that it is packaged and stored to arrive in good condition, especially in the tropics where high temperature and humidity are a constant threat to the longevity of seed stored under ambient conditions. Similarly, better packaging and storage (to maximise longevity) will assist in preserving quality where herbage seed has to be held over for another season due to domestic market fluctuations.

Grasses and legumes produce orthodox seeds (Roberts, 1973), which can be dried to low moisture contents and stored at low temperatures for long periods without loss of viability. General principles that describe the effects of storage environment on seed viability have been developed for crop seeds and are also applicable to the storage of herbage seeds. However, although it is known in general terms that some species are shorter-lived than others, detailed information about the storage characteristics of seeds is lacking for all but the most common herbage species. A high priority for future herbage seed research is therefore to develop more accurate criteria for seed quality management between harvest and sowing based on long-term studies of storage characteristics across a representative range of herbage species.

Seed health. Increasing international trade also increases the need to ensure that herbage seed imports are free from seed-borne diseases and pests. Very few of these have been gazetted for import in most countries, the main ones being bacterial and verticillium wilts of *Medicago sativa* (which were discussed in an earlier section) and khapra beetle (*Trogoderma granarium*), which is regarded as the most serious pest of stored products. Increasingly, adventitious contamination of seed by other plant species is being subjected to analysis by the importing country, because of the potential weed risk posed by certain designated species.

Quarantine requirements do vary considerably from country to country. Some such as Australia, which are surrounded by a continental/island barrier, impose stringent regulations and checks/inspections to keep out the numerous economic pests and diseases that have not yet reached the country. Others with shared land borders have fewer opportunities to prevent the entry of new pests and disease, but still try to ensure that seed traded between countries is free of live pests and seed-borne diseases.

Triggers for change

Over time, the needs and strategies for seed quality assurance in different countries will change. In the first instance, however, this process will be driven by changes in relation to seed of major food crops rather than the smaller markets for herbage seed.

In this context, the developed world has seen significant structural changes in the seed industry over the past decade. These evolutionary changes have been dominated by events in North America and western Europe, which in turn have changed the structure of the delivery mechanisms for new cultivar products into global agriculture. The three main triggers for change have been the development of genetic engineering technology in agricultural species, the widespread adoption of legal arrangements for intellectual property protection for plants, and changes in government policy related to the delivery of quality assurance processes.

Industry re-structuring and consolidation

The practical application of genetic engineering technology to agriculture, which became a commercial reality in 1995, has transformed the focus of much of the developed world's agricultural research and development toward the use of this technology to enhance crop production and diversification of plant products. The main facilitation mechanism in this change process has been the acquisition by transnational chemical companies of existing seed company enterprises. Companies targeted for takeover or merger are strategically located, and with appropriate product portfolios to be operated as the delivery medium for the new seed-oriented plant biotechnology products. This restructuring of the fabric of the seed industry is likely to continue well into the new decade, and will increasingly move into other countries.

The results to date have seen the emergence of a relatively small number of large, multi-faceted seed enterprises, principally based in the USA and western Europe. Many smaller seed enterprises, traditionally the backbone of these important seed markets, have been acquired by larger conglomerates for use as distribution chain networks for products. At the same time, new opportunities elsewhere (e.g. native grass seeds, medi-herbs) are leading to the emergence of small start-up companies, which are more responsive in servicing the special needs of those niche markets than would be possible for a large corporate bureaucracy focused on more traditional seed markets.

Some common characteristics of the new mega-enterprises are as follows.

- High levels of activity in germplasm acquisition, plant breeding and associated cutting-edge technology and down-stream product development are integral parts of the business, resulting in high levels of financial commitment to research and development, often at levels of 5-7% or more of turnover.
- New and emerging areas in plant biotechnology are central to their research and development programs. Alliances with public research institutions (for access to new technology and basic research capability) and even other private corporations (to achieve critical mass and economies of scale for large projects) may be employed for specific research items. Increasingly, however, these new enterprises are conducting their research in-house, principally for the subsequent protection of intellectual property in plant material and information.
- Their product (or cultivar) range is typically large and diverse, but is often restricted to high use crop species such as maize, soybean, canola and the major vegetables. The other main grain products of world agriculture such as wheat and rice are mainly left to public breeding institutions because much of the seed distribution takes place through traditional channels as farm-saved seed rather than through private commercial systems, although this situation is also changing.
- Seed products are both produced and marketed globally through strategically acquired local seed enterprises.
- High levels of internal seed quality management are applied to the marketed products through well resourced programs and laboratory facilities. This applies to all aspects of seed quality: physical, vital, genetic, and phytosanitary. Increasingly, products are not submitted for external quality management programs of seed certification and independent seed testing, but are marketed on brand name and credibility. Included in these strategies is the use by some seed companies of third party accreditation schemes for quality management provided through compliance to quality guidelines under the International Standards Organisation (ISO) or the European Norms (ENs) system. External quality assurance by providers of traditional seed certification and seed testing services are only utilised when market access is not available without this process.
- Products are protected in all markets by intellectual property rights mechanisms such as PBR or utility patents, and by the use of hybrid seed where this is feasible. Marketing may not proceed in jurisdictions where IP protection is not available, both legally and in practice.

While these are the general strategies now operating at the top level of the industry, the same mechanisms are filtering down and, increasingly, are also being taken up by smaller seed enterprises as they strive to maintain their chosen market niche.

So far, a relatively small number of herbage species has been directly involved in this scenario. The principal ones are *Medicago sativa* (lucerne) and the major seeded forage and turf grasses, including *Lolium* spp. (ryegrass), *Festuca* spp. (fescues), *Poa pratensis* (Kentucky bluegrass) and *Cynodon dactylon* (bermudagrass), for which strong private breeding programs (though as yet with relatively little use of biotechnology) are in place. Indirectly, however, other temperate herbage species, in which public breeding remains important, are also caught up in the changing situation because they tend to be marketed as part of a wider product portfolio by the same companies.

There have been recent attempts - relatively unsuccessful thus far - to consolidate the marketing of temperate herbage seeds under the one roof. Comparatively speaking, geographical expansion by some of the major seed companies has been more successful.

With the exception of *C. dactylon*, tropical herbage species are handled exclusively by public breeding programs. This reflects both the relatively small market size for most species and the current difficulties in protecting improved cultivars of a major apomictic species like *Brachiaria decumbens* (see next section for a more detailed discussion). Because of the large number of competing public cultivars, tropical herbage seed markets have also been less attractive to larger national and transnational companies and so far show less corporate consolidation than in temperate markets. Increasingly, though, public institutions are seeking to license their new cultivars to specific private companies, both to manage the transfer of this improved technology and, through royalties, to generate on-going funds for further breeding work. In time, further consolidation in tropical herbage seed markets appears inevitable.

Intellectual property

The introduction of national PBR legislation provides a major catalyst for structural change. It strengthens the seed sector by providing an economic incentive for this, and helping to develop a more professional approach to the supply of quality seed. It is through proprietary marketing that the private seed sector becomes more closely involved in quality assurance, and, in time, may take on the primary responsibility for seed quality management.

Introduction of Plant Breeders' Rights. Recognition of the need to protect the intellectual property embodied in new plant cultivars was the driving force that led to the development of Plant Breeders' Rights. Harmonisation of PBR between countries is provided by the International Convention for the Protection of New Varieties of Plants (Union Internationale pour la Protection des Obtentions Végétales, or UPOV), which forms the basis of existing national PBR laws in UPOV-member States. From the five original signatories in 1961, membership of UPOV has gradually grown to include 45 member states at 31 August 2000 as additional countries have recognised the value of providing IP protection for new cultivars.

During the late 1990s, additional impetus for new countries to introduce PBR was provided by the Trade Related Aspects of Intellectual Property Rights (TRIPs) Agreement under the General Agreement on Tariffs and Trade (GATT), which has the broad aim of stimulating world trade by reducing national barriers. Intellectual property rights were first included during the Uruguay Round of GATT (completed in December 1994). More specifically, the TRIPs Agreement required signatory countries (including some 70 developing countries) to provide either utility patents or a *sui generis* system for the protection of plant cultivars by 1 January 2000. Countries seeking to meet their obligations and the deadline under the TRIPs Agreement invariably did so by becoming member states of UPOV.

PBR protection of new herbage cultivars. Amendments to the UPOV Convention in 1972, 1978 and 1991 have seen a progressive strengthening of the breeder's right, and (under the 1991 Act) the extension of PBR, in theory, to all plant species. At a practical level, however, the scope of PBR remains limited because a complementary all-encompassing definition of breeding (in a legal rather than a biological sense) has yet to be developed.

Like seed testing and quality assurance systems in general, the development of PBR has been driven primarily by the major arable crops and the horticultural sector, rather than the much smaller markets for herbage seeds. For these other crops, the strength of PBR under the UPOV system has always been its relevance to what practical breeders do. The challenge now is to make PBR equally relevant across the whole diverse range of herbage grasses and legumes other that the major outbreeding species like the *Lolium* spp. and *Medicago sativa*, which fit the conventional UPOV model.

The issue to be resolved is whether the genetic constitution of the new cultivar must be changed in some way by the 'breeding' process, or whether the element of discovery implicit in a higher level of selection between existing populations can be rewarded through PBR. The first alternative restricts eligible 'breeding' activities to classical plant breeding, biotechnology and the discovery of mutations. It discriminates against herbage plant improvement, particularly for tropical species, in two main ways. Firstly, provenance (or ecotypic) selection - the main source of cultivars from new herbage species - would not qualify as an eligible activity. That initial stage of plant improvement does involve a planned programme of selection, but at a higher level than allowed under a restrictive definition (i.e. selection between, rather than within, populations). There is also an act of discovery and development, but one related to new economic use rather than to a new combination of plant characteristics. As the species increases in importance, later 'breeding' activities might be eligible for PBR, but these may not occur at all unless there is encouragement for the vital first step. That initial step generally contributes far more than any subsequent hybridisation or selection within populations.

Secondly, a restrictive biologically-based interpretation of breeding effectively eliminates species not readily amenable to classical plant breeding. Apomixis (asexual reproduction) is widespread in more than 30 different families across the plant kingdom, and is particularly prevalent among the current suite of tropical herbage grasses (e.g. *Brachiaria decumbens*, *Cenchrus ciliaris*, *Panicum maximum*). In theory, classical plant breeding techniques can be applied to apomictic species provided a sexual plant can be identified. However, this is a long, involved and costly process; it restricts the breeder's choice to only one of the two parent plants (unless numerous sexual types can be found to act as the female parent as in *Poa pratensis*); and, in practice, successful outcomes have been few and far between (Burton, 1992; Voigt and Burson, 1992).

In apomictic herbage grasses, new cultivars are mostly developed by the direct selection of wild genotypes (Hussey *et al.*, 1997). In the case of *C. ciliaris*, three cultivars produced using a rare sexual plant were released in Texas USA during the 1960s and 1970s (Alderson and Sharp, 1995). Only one of these, 'Nueces', is still in commercial use, though not of major importance (Loch and Ferguson, 1999). Similarly, classical plant breeding has had little or no impact commercially on a number of other predominantly apomictic tropical grasses, including *P. maximum*, *Bothriochloa* and most *Paspalum* species. In the case of *Brachiaria*, it has only become possible in the past 10 years to create hybrids with apomictic *B. brizantha* and *B. decumbens* using a tetraploidised sexual biotype of *B. ruziziensis*, though no improved cultivars have yet been released (Miles and Valle, 1997).

We examined the origin of some 320 seed-propagated perennial tropical herbage cultivars listed by Loch and Ferguson (1999) to determine their eligibility for PBR. Of these, only about 10% of legumes and less than 20% of grasses would qualify under a narrow classically-based definition of 'breeding', reflecting the widespread use and cost-effectiveness of ecotypic selection because of the 'minor' status of most species and the high proportion of apomictic grasses. This result highlights the importance of re-aligning the legal definition of 'breeding' to include the practical activities used to develop improved herbage plant cultivars. A more restrictive outcome was not the intention of delegates at the 1957 Paris Conference that led to the first UPOV Convention in 1961 (B. Greengrass, personal communication). Rather, they opted for a broad interpretation of the French 'obtenteur végétale', which was later translated into English as 'plant breeder' rather than 'plant improver'. What mattered was the result achieved (which should be different from what was previously known) rather than the method of achieving that result.

Integrated protection strategies. PBR[2] is widely promoted as the only independent form of intellectual property protection designed specifically for new plant cultivars; but, in fact, there are four other forms of IP that can be used to protect different aspects of cultivars and their propagating material: trade secrets, utility patents, trademarks, and copyright. As proprietary marketers become more sophisticated, they tend to mix and match the different forms according to their relative strengths and weaknesses, and to back these by the contracts on which the whole system relies. In the case of tropical herbage seeds, there will also be, of necessity, a greater reliance on other forms of IP in the absence of a broader definition of 'breeding'.

Because seed can generally be multiplied by end users, <u>trade secrets</u> have limited application to improved forage and amenity varieties. The exceptions are where there is exclusive control over parent lines used to make a hybrid variety or which are marketed as a physical mixture (or blend).

<u>Utility patents</u> are used to cover ideas (which need not physically exist) and less than 10% of these are actually exploited commercially (Roberts, 1999). Typically, patents are filed at the start of the development process rather than at the end of it, and are defined by claims (in broad or narrow terms) as appropriate in each case. Their major application to plants is in the area of biotechnology (e.g. where a specific gene can be exploited in many different cultivars). Only in USA and Australia are utility patents granted for plant cultivars *per se* on a regular basis. In contrast to patents, <u>PBR</u> is used to protect the products of more traditional breeding methods, and most of them will be exploited commercially.

From this, it can be seen that utility patents and PBR have complementary protective roles in the plant improvement process. Patent rights are for generic inventions, much more speculative and much further back in terms of commercial development. PBR, on the other hand, is for finished products (cultivars) ready for the market. One successful patented invention may ultimately be exploited in many separate plant varieties. Conversely, a single plant variety may incorporate several patented inventions.

PBR is an effective tool in managing seed production because it applies to the actual material (the cultivar). However, for a proprietary variety to be marketed successfully, it must be clearly differentiated in the market and readily recognised by end users. Relying solely on PBR here can be a disadvantage because the name used to promote a superseded variety (even where it

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[2] For practical purposes in the present paper, PBR as a form of intellectual property can be regarded as including the unique US Plant Patent system, which applies to asexually reproduced varieties.

has good market appeal) will be lost along with it. The worst case scenario would be a major economic species where strong breeding activity led to a large number of very similar cultivars and a rapid turnover of these in the marketplace.

A trademark applies only to the name used for marketing purposes. It does not apply to the cultivar *per se* and so has weaknesses relative to PBR when it comes to managing seed production. However, this becomes its strength as a marketing tool because the name can be retained after the original variety has been superseded, thus maintaining consumer recognition and continuity. Increasingly, trademarks are being combined commercially with PBR and other forms of IP to give the best of both worlds (e.g. *Cynodon dactylon* cv. Tift 94 is registered that way for PBR[4], but is marketed under the name TifSport™).

A trademark alone provides weaker proprietary protection for the production and marketing of an improved cultivar, but this may not matter unless there is a strong market incentive for competitors to multiply and promote the same material under another name. In that case, the use of copyright to cover the expression of promotional material would provide additional protection. This demonstrates an important strategic point in relation to IP protection: first decide the best aspect of IP to protect in that situation, or, alternatively, what aspect(s) can be protected, because this determines the best form(s) of IP to used in each particular case. For the first cultivar of a new economic species, the act of discovery is directed more towards its economic use and the supporting technology rather than the 'newness' of the material *per se* - hence the suggested combination of a trademark (on the marketed name) and copyright (on the written material that contains the technology of use).

Government policy to deregulate

The final major driving force for structural change in the seed industry, beginning in these developed economies, has been the tendency for governments to deregulate most areas of seed quality management. Instead of industry regulation by official standards set by government, industry is being encouraged to undertake (through accreditation systems) the provision of those quality control functions that previously were the exclusive domain of government.

These measures have moved the QA activities as such and their cost, together with the legal liabilities, from government to the private sector - specifically, to the seed industry as a whole, and its members in particular. While self-regulation is often seen both by government and industry as a progressive measure, only time and experience will indicate whether this process better serves the consumer than the regulatory mechanism previously employed by governments.

The success of the transition will depend greatly on the jurisdiction in which the activity occurs, being perhaps better operated within developed countries with the necessary resources available through the private sector. In contrast, strategies based on government intervention in the public interest may still be more appropriate for developing economies.

Changes in philosophical approach by governments and a willingness by industry to take a greater role in their destiny have, at least at the international level, resulted in better coordination and cooperation between major players in seed quality management than has previously been the case. This is emphasised in the high degree of consultation now being undertaken between bodies such as OECD, UPOV, FAO, ISTA and the International Seed Trade Federation (Fédération Internationale du Commerce des Semences, or FIS) on matters of mutual concern.

Global Trends in Quality Assurance

European countries have retained a centralised regulatory model with official standards (policed by inspectors), together with national listing of approved cultivars. Such arrangements tend to operate against change. However, other developed countries, unfettered by the rigidity of national listing, are moving to more decentralised quality assurance systems in which the legal responsibility increasingly falls on the seller. Currently, the most extreme example is Australia where this led to the introduction in 1999 of a National Industry Code of Practice for Seed Labelling and Marketing under the Trade Practices Act (Anon., 1999). The key provisions of the Code (which is replacing long standing State and Territory seed legislation in Australia) relate to labelling requirements, prohibited seeds/pests/diseases, seed quality assurance, marketing, promotion, and alternative dispute resolution. The Australian seed industry is now implementing a separate business unit (SeedQual Australia™) to manage the operation of seed certification in Australia based on accreditation and independent auditing of licensed service providers (Melham, 2000).

Seed company quality assurance

For many years, the larger seed companies have traded their products on the basis of brand name with quality guaranteed by the company. This is an appropriate strategy on domestic seed markets, but not for international trade unless equivalence of quality management protocols can be achieved. A case in point has been the need for most imports of seed into the EU to be restricted to closely defined protocols of equivalence, which have not recognised company quality assurance.

Product quality is monitored by 'in-house' quality management systems utilising the principles of varietal certification during seed production and testing for physical, vital, and phytosanitary quality where appropriate through laboratory-based diagnostic protocols. While all of these activities are often undertaken as part of company operations, specific tests may be contracted out to specialised private or government-operated testing agencies where this is financially or technically appropriate. 'In-house' quality management operations provide the advantage of rapid feedback on product quality prior to marketing, which is often in a short time frame, and also minimises potential loss of control over proprietary material.

To strengthen assurance to customers, as well as formalising quality management strategies within operations, some firms have instituted ISO- or EN-based quality systems monitored for compliance by third party audit. However, such situations are rare, although they may increase in the future under pressure from regulatory requirements for marketing of seed of species where there is a risk of adventitious contamination of transgenic cultivars. Increasingly, smaller-sized seed companies, including those trading in herbage seed, are implementing formalised 'in-house' quality assurance strategies, and some of the larger temperate-based companies may also operate their own seed testing laboratories.

Role of non-company QA agencies

Traditionally, governments have provided quality assurance programs for use by the seed industry. Generally, these have been varietal certification programs for genetic integrity and diagnostic services both for seed physical and vital attributes and for phytosanitary quality. These ‘official’ systems are often linked to the need for the market to comply with regulatory standards imposed as consumer protection measures by governments.

In recent years, full commercial fees for government services have come into effect in many developed countries, reflecting trends towards a reduction in agricultural subsidies and compliance by government agencies with competition policy. This has enabled the establishment of private businesses providing seed quality management in competition with government agencies, which have traditionally serviced the industry. Both privately-owned varietal certification agencies and (particularly) laboratory-based diagnostic service providers have entered the marketplace. This trend is likely to continue, with the consequence that some government providers are likely to cease operations as a consequence of financial loss through competition or where government is unwilling to provide services in the absence of demonstrable market failure.

Where specific regulatory requirements are imposed on the seed industry by government, there is an increasing trend to allow private service providers to conduct their quality management operations under accreditation protocols. Compliance may be monitored directly by government; but, increasingly, this is being monitored on behalf of government by third party auditing organisations.

Changes in international systems

Significant changes in the operation of international quality management protocols, which are the essential framework for trans-boundary movement of seed, have taken place over the past decade. As a consequence, changes in seed quality management systems for domestic markets have also been facilitated.

Since 1993, countries operating the OECD Schemes for the varietal certification of seed moving in international trade have been evolving protocols to transfer operation of the Schemes from government to private sector providers. The framework under which these changes have been made is based on the accreditation of providers under guidelines compatible with ISO and EN Standards.

Utilising the facility of experimental derogations to legal provisions, the OECD allowed for accredited operation of field inspection protocols in 1994. Subsequently, this arrangement was extended to other elements of the ‘Rules and Directions’ in 2000, specifically those related to seed sampling and testing and to product labelling. The effect of these changes has been to facilitate private sector involvement in ‘official’ activities of government responsibility. In general harmony with OECD, the countries of the EU have conducted similar derogations of legal protocols required for marketing of seed in the Community.

In 1995, ISTA instituted changes allowing private, independent laboratories to become accredited members. This enabled them, along with government member laboratories, to be authorised to issue international seed lot reports on which a considerable amount of international seed trade, particularly in herbage seed, is conducted. This facility was extended in February 2000 to seed company laboratories.

In 1994, the first International Seed Health Initiatives (comprising seed pathologists from industry, inspection services and other institutes) were formed to work on standardisation of testing methods for economically important seed-borne pathogens of vegetable crops. These were followed in 1998 by similar initiatives for herbage and field crops. In 1996, ISTA and the vegetable ISHI agreed to collaborate in the evaluation of standardised seed health tests, and the joint publication by Sheppard and Wesseling (1998) of guidelines that established for the first time procedures to be followed in the validation of seed health testing methods. Both transnational seed movements and internal phytosanitary issues can now be managed using a comprehensive suite of internationally recognised tests.

Conclusion

High quality seed is essential for the successful establishment, uniform growth and maximum productivity of any crop species - agricultural, horticultural, and herbage - and quality assurance is an integral part of any seed supply system. Current changes taking place in relation to seed quality management in developed countries are not jeopardising the achievement of this objective, but rather taking it to a new level in which the private sector has a vested interest in ensuring that QA operates effectively.

The current changes are being largely driven by the developments in relation to arable crop seeds, with herbage seeds being swept along as part of the wider seed sector. In general, the implementation of these changes for herbage seeds has lagged behind that in other parts of the seed sector, partly because of the small market size for many crops and partly because of the idiosyncrasies of herbage seed markets. Forage seed markets in particular are relatively unsophisticated. Seed price (rather than physical and vital quality) is often the dominant consideration for farmers purchasing forage seed, especially in tropical countries where the concept and value of using quality seed need to be promoted. To this end, there is a need to develop more cost-effective in-house QA systems to provide at least some protection against genetic drift in outbreeding tropical forage cultivars.

An underlying factor that contributes to the current overemphasis of price, particularly with tropical forage seeds, is the limited role for PBR in many species. The challenge is to develop an all-inclusive definition of ‘breeding’ that extends eligibility, both in practice and in theory, to all species. Until then, the only option for proprietary marketing of many cultivars is to devise alternative strategies based on the integrated use of other forms of IP.

Herbage seed markets, however, are changing, and will increasingly become more sophisticated. The growing demand for non-traditional foods, including meat and milk, in developing countries as disposable incomes rise will be reflected in increasing demand for better quality forages and forage seeds for animal production. On herbage seed markets, however, the more rapidly growing component is amenity seed, and this trend will continue as the demand from leisure and environmental markets also continues to grow into the 21st century.

In developing countries, the traditional QA model is likely to continue for the foreseeable future, with governments taking on the role and responsibility for managing herbage seed quality in the public interest. In time, however, developed countries should see the gradual implementation for herbage seeds of changes now happening elsewhere in the seed industry, as the private sector takes greater legal and economic responsibility for QA. Herbage seeds are not grown and marketed in isolation from other parts of the seed industry, and so are not insulated against new developments in seed quality assurance. Now is the time to study those changes and to facilitate their wider implementation in relation to herbage seeds when this occurs.

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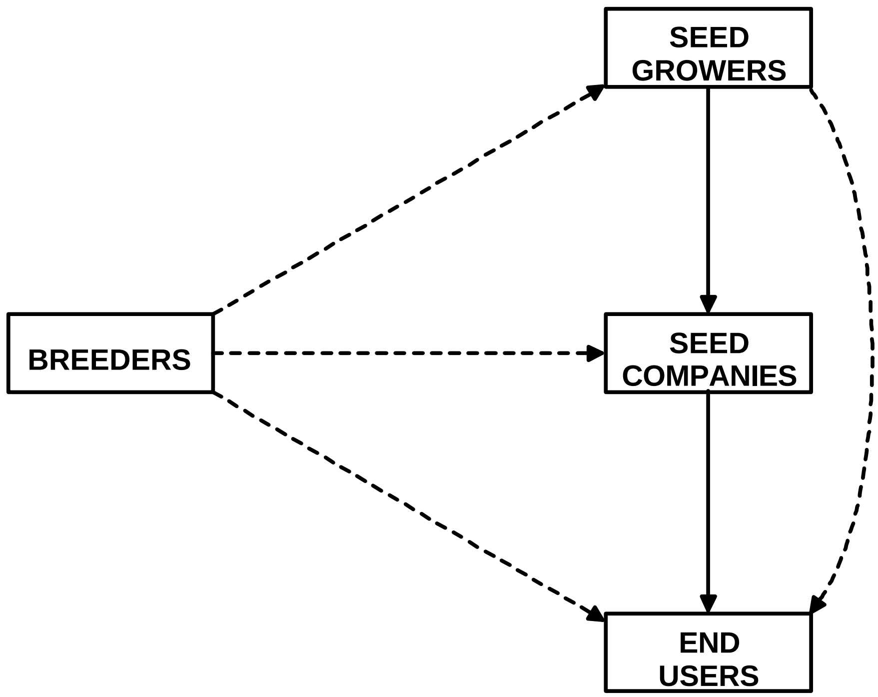

Figure 1 - Seed flow diagram for a public cultivar. Dashed lines indicate secondary or more diffuse relationships (Loch, 1997).

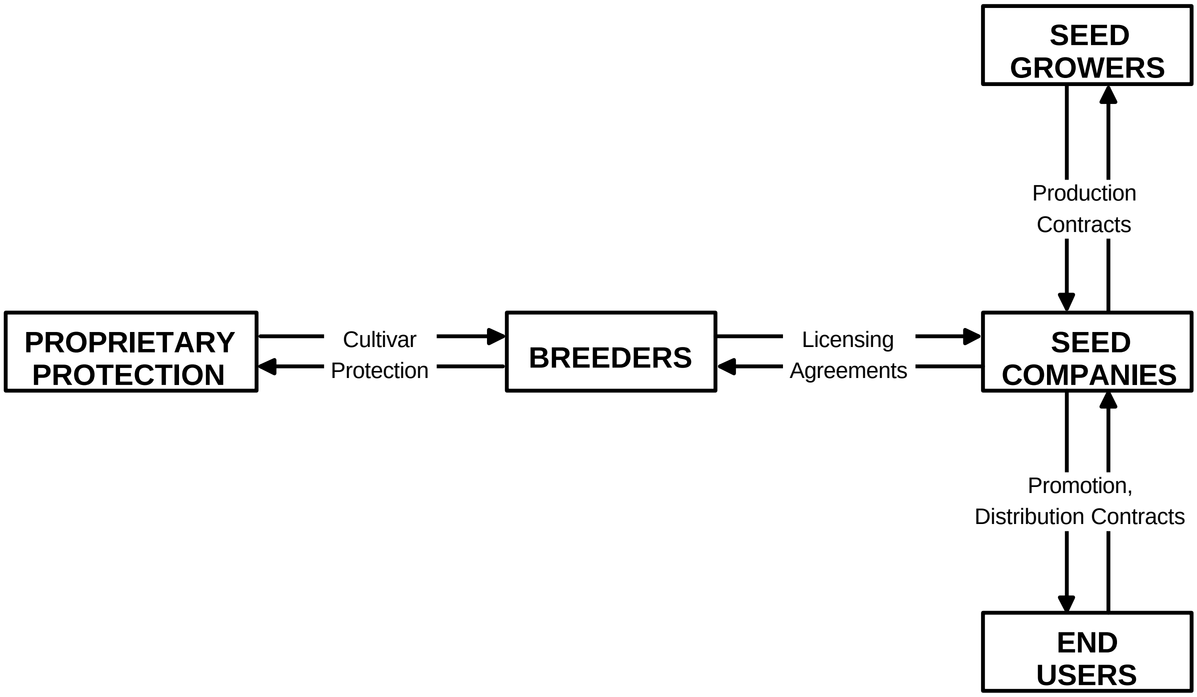

Figure 2 - Seed flow diagram for a proprietary cultivar (after Loch, 1997).