Quality seed production and effective marketing systems for development of grasslands

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ABSTRACT

Seed quality is defined as (i) maintaining genetic purity using seed certification principles (generation system; isolation; previous cropping history); (ii) achieving high levels of physical purity (especially low weed seed levels) by in field weed control and seed cleaning; (iii) achieving high levels of seed germination at harvest and maintaining germination through the seed supply chain. Seed production systems must not only produce high quality seed but also achieve economic seed yields. Seed crops have to be profitable (by being high yielding) to justify the investment of time and input costs to achieve quality. This in turn requires supporting research and extension to seed growers.

Effective marketing requires a seed supply chain from the forage user back to seed producer i.e. it should be demand driven. Creating demand requires on farm trials and demonstrations to develop awareness and to move end-users away from commodity price-sensitive thinking. End users must understand the need for, and value of, paying a premium price for quality seed and for new cultivars that can add value to crops and livestock. Four seed supply chain models are discussed.

Key words: Germination, genetic purity, physical purity, supply chain.

Introduction

Seed production systems need to produce high quality seed (physically and genetically pure, with good germination) at affordable prices for the end user but economically profitable for the producer and have effective seed supply chains to deliver the seed to end users. This paper examines what defines quality; the systems to assure quality standards are achieved and marketing and seed supply chain options to demonstrate forage value and deliver seed.

Seed Quality: There are four basic attributes of seed quality: genetic purity, physical purity, seed germination and phytosanitary quality. Issues related to forage seed quality, dormancy, standards and quarantine including phytosanitary quality are covered by Hampton (2015).

Genetic purity: Seed certification schemes are designed to ensure that the genetic attributes of a cultivar are maintained. The three principle tools to maintain genetic purity are isolation distance, previous crop history and the generation system. Seed certification systems are often linked to the Organisation for Economic Co-operation and Development (OECD) "Schemes for the Varietal Certification of Seed Moving in International Trade" (OECD 2015) or to Association of Official Seed Certifying Agencies (AOSCA 2015). However, national schemes often based on either OECD/ ASOCA are also operated in many countries using the same or similar rules to manage genetic purity. For some species, seed companies develop "in-house" quality assurance schemes modelled on OECD/ AOSCA. The OECD/AOSCA standards are the minimum standards and some countries choose to implement these schemes with a higher standard. Loch and Boyce (2001) comment that different strategies are needed for cross pollinated species that require "pedigree certification" to minimise genetic drift by limiting the number of generations a cultivar can be multiplied compared to self-pollinated and apomictic species where "pure line certification" can be used as there is a low probability of genetic drift.

***Isolation distance*:** the distance between the seed crop and another cultivar (or species) that can cross pollinate or physically contaminate the crop. The distance depends on the breeding system (cross or self-pollinated) and is typically 50 to 100 m for cross pollinated crops and 5 to 10m for self-pollinated crops. Small crop areas, <2.0 ha have greater isolation distances than crops >2.0 ha and higher grade seed (basic or pre-basic) has greater isolation distances than lower grade (1st or 2nd Generation) seed.

***Previous cropping history*:** the number of harvest seasons since the last crop of a different variety of the same species (or a species with similar seed characteristics) was grown. This is often two harvest seasons, but depends on whether dormant and therefore viable seeds of the species are retained in the seed bank.

***Generation system and degrading*:** Seed Certification usually has three or four grades (Breeders; Basic or Registered; First Generation and Second Generation. Seed sown with one generation (e.g. Basic) produces seed of the next lower generation (First Generation). To maintain genetic purity seed sown to produce a certain grade of seed may be further degraded to a lower grade after one or two harvests for multi-year cross-pollinating crops; e.g. tall fescue may produce Basic seed for two harvests and then is downgraded to produce First Generation seed for any subsequent generations.

***Seed certification agency and field inspection*:** For seed quality assurance to work there is a requirement for a farm identification system with maps and fields identified by unique numbers or letters. Records of previous crop histories over five years in each field, and a process of entering fields into Seed Certification and providing evidence of the parent seed sown are also required. To ensure that standards of isolation and crop hygiene are being met, at least one field inspection by the Seed Certifying Agency is required, usually at flowering; or if more than one inspection, then at establishment followed by a flowering inspection.

***Seed cleaning*:** While pre-cleaning may occur on farm, it is common for final seed cleaning to occur off farm. Seed containers (bags, boxes) need to be identified by species and cultivar before they leave the farm. Seed cleaning stores (the building) and the operators (people) are usually licenced to handle Certified Seed and subject to inspections. Seed sampling for seed testing is undertaken by trained staff of the Seed Certification Agency or by licensed seed samplers and the methods used are prescribed by the International Seed Testing Association (ISTA, 2015).

***Pre-basic high grade seed production*:** Between the completion of breeding and the resulting handful of seed produced from the final multiplication of parent plants and the start of the seed certification process are pre-basic seed multiplication steps, usually involving two or three generations (Rolston and Gomez, 1986). Quality control to ensure genetic integrity is maintained is critical and any mistakes at this step can lead to contamination issues appearing during commercial seed production and potential rejection from Seed Certification.

Physical purity: Seed Certification often attempts to limit the spread of weeds by imposing standards on the occurrence of noxious weeds at field inspection. Weeds can be described as being either competitive (they reduce seed yield) or as seed cleaning weeds; i.e. they are hard to remove during seed cleaning and good seed is lost in the process of removing these weeds. While herbicides are a primary tool for weed removal, in seed production all aspects of good weed management need to be practiced including rouging, stale seedbed preparation (where land is cultivated at least three weeks before sowing to allow weeds to germinate and then sprayed with a non-selective herbicide like glyphosate or paraquat at sowing time), crop rotations, stubble burning, using clean machines and equipment, keeping irrigation channels, hedge rows and fence-lines weed free and allowing grazing animals to 'empty out' so viable seeds in faeces do not contaminate seed crops. This process takes 36 hours before animals can graze seed fields. Physical purity is also affected by inert material, straw, glumes and diseased seed like ergots (*Claviceps purpurea*) that are common in many grasses and weed seeds that have been modified by over-threshing e.g. dock (*Rumex*) in red clover, wild oat (*Avena fatua*) in fescues and ryegrass or *Sherardia arvensis* in white clover. In terms of a quality standard the physical purity is often expressed as a minimum purity (e.g. 85 to 95% for tropical species, and 95 to 98% in temperate species), but usually not containing more than 0.3 to 0.5% other seeds (crop and weed seeds). The exact numbers very between certification grades and species of crop.

Pure seed is not always easy to assess especially in some tropical species where the seeds may be chaffy and not free flowing in an air column and it is difficult to separate seed like structures that do not contain a caryopsis (e.g. *Andropogon*, *Cenchrus*, *Chloris* spp.) (Loch and Boyce, 2001).

Seed germination: Good seed germination is an important seed quality attribute. In some grassland species determining germination is complex because of seed dormancy issues requiring the use of chemical additives and fluctuating temperatures as pre-test treatments (Hampton, 2015). While ISTA has defined testing rules for most common species, defining germination test requirements for native grassland species (e.g. in China) is still being researched (Zheng *et al.* 2009; 2014).

In grasses, management practices (crop density, nitrogen, fungicides) are needed to minimize seed diseases that reduce germination (such as blind seed *Gloeotinia temulenta* (*syn. Phialea temulenta (*Chynoweth *et al. 2012*). In *Bromus* species smuts *(Ustilago* bullata Berk) is a seed borne diseases that reduce seed quality (Falloon *et al*. 1988). Seed harvesting practices especially very hard threshing in legumes to remove seed from pods and floret structure, can result in bruising and seed damage resulting in the production of abnormal seedlings. Seed cooling at harvest and seed drying are essential to reduce seed germination loss from fungal growth and heating from storage fungi such as *Aspergillus spp. a*nd *Penicilium spp.* (Hill, 1999). Harvesting immature seed results in seeds with low thousand seed weight (TSW) and reduced germination. Managing seed crops to compress flowering and seed set increases seed quality and can be done with spring defoliation of some grasses (e.g. *Lolium perenne*) and legumes such as red clover (*Trifolium pratensis*) or lucerne/alfalfa (*Medicago sativa*), but with many indeterminate flowering herbage species it is difficult to compress flowering e.g. trefoil (*Lotus pedunculatus*) or chicory (*Chicorum intybus*).

Achieving high germinating seed in tropical species is a challenge (compared to temperate species) because of the wider range of flowering times resulting in more immature seed in the sample and compounded by differing physiological seed dormancies that are difficult to break. Temperate seeds (with the exception of cocksfoot) are often traded at a minimum of 90% germination (cocksfoot 85% germination). In contrast, tropical grasses are typically traded with minimum germination or viability of 70%, determined by either a germination test and/or by a tetrazolium viability test (Loch and Boyce, 2001).

Pure live seed: Tropical seeds with their lower purity and germination are typically traded on a pure-live seed (PLS) basis. Temperate seeds tend to be traded on a minimum purity and germination (P&G) basis e.g. 98/90 (purity/ germination) for *Festuca* and *Lolium* or 90/85 for *Dactylis*.

Endophytes: Vertically transmitted *Ephicloë* fungi that protect grasses from insect pests are an important attribute in many improved grasses (especially in *Lolium* and *Festuca* species), and especially endophytes that are safe for grazing animals (Johnson, *et al*. 2013). Delivering high levels of viable endophyte is an added challenge for seed marketing (Rolston and Agee, 2006).

Temperate vs tropical species: Loch and Boyce (2001) discussed why seed certification has not been fully accepted in the tropics and cited the following reasons: (i) there are fewer released cultivars; (ii) that genetic variation is often valued and at times physical mixes of seed may be sold to achieve this; (iii) many tropical species are predominantly or wholly apomictic (e.g. most *Brachiaria*) or strongly self-pollinating (most legumes).

***Stage of national development*:** Linked to the above, Loch and Boyce (2001) also noted that the level of seed quality assurance (QA) used by a country is linked to the stage of national development. In a developing country the first steps are simply to make herbage seed available to ensure it has been tested for purity and germination, and to ensure that seed is "truthfully labelled". Gradually as herbage seed production develops and people are trained, other aspects of seed quality assurance can be added. They note "this is a process of evolution in which a highly sophisticated quality assurance system is not warranted during the early stages".

***Seed yield*:** Achieving an economic seed yield that results in herbage seed crops being profitable compared to other crop/livestock options is essential to justify the extra investment of time and costs to achieve quality. Seed growers need to be supported by field based research to solve production problems, on-farm demonstrations, cost/benefit and risk analysis of new technologies and efficient extension programmes to assist them to achieve higher seed yields and profits. Elements of successful seed grower extension programmes in New Zealand are described by Pyke *et al*. (2015) who note that farmers need to recognize that to remain competitive they need to implement new practices, and that farmers need to be involved in the research and development of new practices.

Effective marketing system

Effective marketing requires a seed supply chain that links back from the grassland farmer (end user) to the seed producer (Fig. 1). In many markets demand is focused on price sensitive (cheap) commodity seed; not a demand for the right cultivar and species to meet the end-users farm system and environment. Effective marketing involves educating growers on options and creating an understanding of value through on-farm trials or demonstrations to create awareness. It is only when there is a perception of value for certified seed and seed of good quality that end-users will pay a premium price. This will pay for quality assurance in seed production and allow breeding companies to further invest in new cultivars.

***Agronomic performance*:** In many countries agronomic performance has been dropped as a criterion to register a variety or to enter Seed Certification, and entry is solely on meeting DUS (distinct, uniform and stable) criteria. Agronomic performance testing has generally moved from government testing to private testing. It is then a marketing tool and becomes the role of the breeder/seed company which may undertake the trials or sub-contract some trialling to neutral third parties e.g. Universities or independent testing companies. When well developed markets become cluttered with many cultivars delivering small benefits and relying heavily on advertising to gain sales, end-user farmer funded research may be employed to identify best cultivar options. In New Zealand the Forage Value Index (FVI) is an attempt to rank the economic value of different cultivars in different regions (Chapman *et al*. 2012, 2013).

Seed coating/rhizobia delivery*:** Marketing systems should be able to provide rhizobia for legumes; either incorporated into seed coats or separately for farmers to apply to seed at sowing time. Seed supply chains should also be able to deliver seed coatings to improve establishment; these may include nutrients and fungicides to reduce damping-off caused by the soil borne pathogens *Pythium* and *Rhizoctonia spp.**

***Seed storage*:** Seed supply chains need good storage. Seed store design should minimize temperature and relative humidity fluctuations, have adequate ventilation and be dry. Seed should not be stored directly on floors, but be elevated at least 5 cm above the floor on wooden racks. Stores should be free from rats, mice and birds. Seeds packaged in moisture proof bags/containers will maximise seed longevity in the seed supply chain.

Seed chain marketing models

1. ***Local production for local markets (e.g. Nepal)*:** Where there is a demand for forages in regions with poorly developed seed supply chains, local seed production to meet local needs is an option. In Nepal the demand for winter active forages (legumes and grasses and forage oats) has outstripped supply. A local production model is being developed using local village crop seed cooperatives with training from the Nepal Agricultural Research Council (NARC) and Department of Livestock Services with technical support from the Lincoln University (NZ) Seed Research Centre. Some key components include local farmer owned co-operatives reselecting from existing cultivars the best plants to create new locally adapted material, and the adoption of seed quality assurance procedures to deliver quality seed.
2. ***Village based production for local and international markets (e.g. Thailand)*:** Village based seed production of tropical species under contract to a marketing/ distribution company has worked well in Thailand (Hare, 2015). Key elements in this model are farmer training and contracting to purchase seed, on-farm pre-cleaning and seed drying, centralized final cleaning to international standards, and seed treatments to remove dormancy restrictions. The production system relies largely on manual operations from planting to weeding to harvesting for

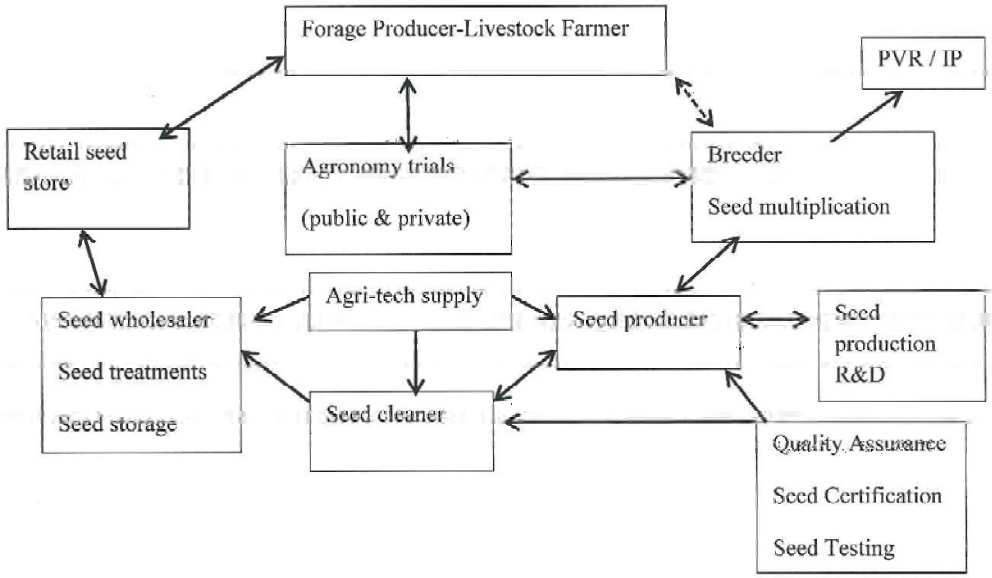

Fig. 1. Diagrammatic representation of the seed supply chain (PVR = plant variety rights; IP = intellectual property; R&D = research and development).

species for which it has proven difficult to achieve quality seed with mechanized harvesting. In the 2014-15 seed harvesting season, 130,000 kg of seed comprising eight forage grasses: Mulato II , Cayman and Cobra hybrid brachiaria (*B. ruziziensis* x *B. decumbens* x *B. brizantha*), Mombasa guinea (*Panicum maximum*), Tanzania guinea (*P. maximum*), Ubon paspalum (*Paspalum atratum*) and two forage legumes: Ubon stylo (*Stylosanthes guianensis*), Greenleaf desmodium (*Desmodium intortum*) and one green manure legume: Sunn hemp (*Crotalaria juncea*), were harvested for seed by over 1,000 village farmers in northeast Thailand and northern Laos (Hare, 2014, 2015).

3. ***Integrated Breeding-Production management-wholesale/retail (e.g. New Zealand)*:** The most common model in developed countries is based on large companies that are both breeding and marketing to either the wholesale and/or retail level. This system works well for large volume species, especially lucerne (*Medicago sativa*), ryegrass (*Lolium perenne, L. multiflorum*) and tall fescue (*Festuca arundinancea*). For the breeding component public/private partnerships may be undertaken but the marketing is the seed company's role. Seed quality assurance is undertaken by a government agency acting as the delegated authority to OECD and AOSCA.

4. ***Public breeding-cultivars/germplasm licensing to private companies or breeders (US model)*:** A traditional approach to marketing systems involves public funded breeders developing germplasm and/or partially or fully bred cultivars that are given or licensed to seed companies to develop and market. If cultivars are involved the maintenance of high grade

seed usually lies with the breeder. The release of cultivars by public breeders was common in developed countries from the 1930s to the 1980s but with the development of plant breeding/seed companies and access to intellectual property (IP) protection by way of Plant Breeders/Variety Rights it has largely been replaced by Model 3. However in the US, public breeding and release of germplasm, especially by Universities, is still a common practice; e.g. Rutgers University is one of the largest turf grass breeders in the US, supplying pre-breeding material to many companies. The role of public breeding is important for minor species with important niche roles in grasslands where the market size makes cultivar development, maintenance and marketing un-economic, and in developing countries where IP protection is unavailable or not providing adequate protection to breeders. Equally, many small seed companies (often farmer companies producing niche species) have been formed to market small volume species and varieties; e.g. native seeds where IP protection comes from some unique seed harvesting or seed processing step; e.g. de-awning or de-fluffing processes.

Conclusions

The production of high quality seed requires end-users who value quality and are prepared to pay a premium above commodity seed prices to cover the costs of quality assurance. There is no one model for delivering quality assurance and the model used need to reflect the stage of national development. Seed supply chain systems generally fit one of four models and the models have evolved to meet different demand and supply volume situations.

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