Quality and seed production in New Zealand

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Abstract

Seed quality refers to a number of seed related properties which may have varying degrees of practical importance for agriculture. Analytical purity and germination have been the two factors most commonly used in assessing seed quality, but increasingly, information on other quality attributes is required. The present quality status of New Zealand produced seed lots is reviewed, and the importance of seed quality data assessed. Seed production is often for quantity, not quality. The need for research to overcome quality seed production problems is outlined.

Additional key words: *analytical purity, cultivar purity, germination, seed analysis, seed moisture, vigour.*

Introduction

Quality can be defined as "all the features and characteristics of a product or service that bear on its ability to satisfy a given need", and thus Esbo (1980) referred to seed quality as "a collection of seed components considered to be of importance for the value of seed for sowing purposes". Traditionally, analytical purity and germination capacity have tended to be the only properties of seed considered when assessing seed quality (Scott and Hampton, 1985), and in 1990, 73% of the 11,643 analyses carried out at the Official Seed Testing Station in New Zealand were for purity and germination only (A.A. Johnson, pers. comm). However, there are many dimensions to the concept of seed quality (Thomson, 1970) which may have varying degrees of practical importance for agriculture. Coolbear and Hill (1988) suggested that components of seed quality fall into three categories, i.e., accurate description, hygiene, viability and potential performance. I have modified their suggestion to:

1. **Description:** species and cultivar purity; analytical purity; uniformity; seed weight
2. **Hygiene:** noxious weed contamination; seed health; storage fungi contamination; insect and mite contamination
3. **Potential Performance:** germination; vigour; moisture content; field emergence and uniformity; storability

Availability of quality seed is an essential requirement for agricultural and horticultural production, and in New Zealand, seed certification has been an effective form of quality assurance for agricultural species since its introduction in the 1920s (Hampton and Scott, 1990). The Minister of Agriculture and Fisheries is empowered under the Ministry of Agriculture and Fisheries Act 1953, Section II (Appendix III) to provide seed certification services, and the scheme is administered by MAF Quality Management using procedures that are in accordance with OECD rules. However, New Zealand has no seed laws (Scott and Young, 1984), and participation by the seed production industry is entirely voluntary, although participants must adhere strictly to the rules and procedures involved.

New Zealand now participates in the OECD herbage and oil seed, cereal seed and beet seed certification schemes. In 1991 cultivars of 14 herbage or amenity grass species, 6 herbage legume species, 1 forage herb species, 5 cereal species, 4 brassica species, and 1 each of lupin, pea, linseed and beet were eligible for OECD certification in New Zealand, and in 1989, 5000 t cereal seed, 500 t brassica seed, 500 t pea seed and 14000 t herbage seed was certified. Total annual production can fluctuate widely; for example, New Zealand's herbage seed production for 1980-89 averaged 20,600 t, with a range from 13,360 t in 1989 to 34,590 t in 1988 (Rolston *et al.*, 1990) mainly in response to unstable export market requirements.

Because there has been no demand, the New Zealand seed certification scheme does not include horticultural pecies (with the exception of one cultivar of *Phaseolus vulgaris*). For those species which it does include, it does not cover most components of seed quality. The scheme aims to provide the consumer with seed of high cultivar purity and a minimum standard of analytical purity. No guarantee of this is given, other than to certify that an acceptable procedure has been followed to attain this goal (Anon., 1991).

Present Quality Status

Germination

The absence of germination minimum standards means that low or non-viable seed lots can be sold. The onus is always on the purchaser, and "check the seed analysis certificate before buying" has long been good advice. Consumers have generally come to expect germination values of at least 90% in seed lots of most species they grow, and seed lots for export must obviously meet the standards of the importing country. In practice a germination test result of less than 90% means that providing dormancy is excluded, the lot contains dead seeds, and/or abnormal seedlings. This indicates that the quality of the lot is suspect, and that there may be future problems with field emergence or ability to be stored (Hampton and Coolbear, 1990).

In 1991 26% of the seed lots for which data are provided failed to reach 90% germination (Table 1). While a small number of these results were from retests of stored lots, most were from tests on seed lots produced in the 1990/91 harvest season (A.A. Johnson, pers. comm.).

Herbage species: Grass and legume seed lot germinations (Table 1) are similar to those reported for the 1984 season (Scott and Hampton, 1985). Low germination in perennial ryegrass is commonly associated with dead seed resulting from blind seed disease (caused by the fungus *Gloeotinia temulenta*), heating damage or immature seed (Hampton and Young, 1985), but little published information exists as to reasons for low germination in many other grass species. The germination of cocksfoot can be improved by reducing the percentage of multiple seed units in the lot and by increasing mean seed weight (Scott and Hampton, 1985). Blind seed disease has recently been associated with low germination in tall fescue, although, whether this is the sole cause of the problem has yet to be determined.

Low germination in herbage legumes very often results from the presence of hard seed, so that while viability may be 90% or greater, hard seed levels of 10-20% are common, particularly in red clover, lotus and lucerne (Scott and Hampton, 1985). High numbers of abnormal seedlings or dead seed have been associated with poor harvest technique (Miller,1988) or physical damage incurred during attempts to reduce hard seed content (Viado, 1989).

Cereals: In New Zealand, the germination of cereal seed lots is usually greater than 90% (Hampton, 1981), and the 1991 wheat data (Table 1) suggest that this is still so. Occasionally however, problems do arise. For example, in 1980-82, the germination of over 30% of Karamu, Rongotea, Oroua and Tiritea wheat seed lots was significantly reduced because of the development of plumular abnormalities (Scott *et al.*, 1985). The problem was eventually linked to mechanical damage from a device designed to remove attached glumes. Bypassing the device produced undamaged seed, and in 1983, 87% of lots had a germination of over 90%. Similarly in barley, germination was reduced in 1986 by the presence of a seed borne fungus (*Bipoloris sorokiniana*) which caused abnormal seedling production (Cane and Hampton, 1990). Fungicide seed treatment controlled the pathogen and prevented the formation of abnormal seedlings during the germination test.

Table 1. Germination of seedlots tested in New Zealand between January and June 1991[1].

Species	Percentage of seedlots in each germination category			Total seed lots
	<80%	80-90%	>90%	
Grasses				
Lolium perenne	5	13	82	1,547
Dactylis glomerata	8	48	44	153
Festuca arundinacea	8	32	60	187
Agrostis capillaris	3	19	78	69
Legumes				
Trifolium repens	2	10	88	1,063
Trifolium pratense	33	55	12	203
Lotus uliginosus	21	57	22	87
Medicago sativa	34	52	14	69
Cereals				
Hordeum vulgare	11	6	83	53
Triticum aestivum	0	5	95	191
Others				
Chichorium intybus	61	34	5	26
Phaseolus vulgaris	36	36	28	14
Allium cepa	60	30	10	10

[1] Data provided by the Official Seed Testing Station, Ministry of Agriculture and Fisheries, Palmerston North, New Zealand.

Other Species: Little is known of the reasons for low germination in seed lots of other species in New Zealand (e.g., Table 1), although it is probable that mechanical damage and seed moisture content are usually involved. For example, bean seeds are particularly susceptible to mechanical damage arising from incorrect harvesting and processing techniques, and Scott (1985) reported that the germination of asparagus seed was reduced because freshly harvested seed was not adequately dried before storage. Low germination in chicory (Table 1) is thought to result from harvesting too early, resulting in immature seed in the lot (Hare *et al.*, 1990). Hare (1986) also considered that germination increased with increasing seed weight.

In general, the size of the crop (in terms of number of fields and hectares), and/or the 'newness' of the crop tend to determine the extent of germination problems, because of a lack of grower expertise. Thus germination of seed lots of phalaris, dogstail and timothy is much poorer than seedlots of perennial ryegrass (Scott and Hampton, 1985; A A Johnson, pers. comm.), and germination problems with evening primrose and white mustard, in addition to those of chicory, have been recently recorded.

Analytical purity

For certified seed crops, analytical as well as cultivar purity standards must be met. For example, to be certified as 1st generation, a white clover seed lot must have a minimum of 97% pure seed, and contain a maximum of 0.5% other crop seed and 0.5% weed seed (Anon., 1991). Rowarth *et al.* (1990a) reported that 12% of the 537 white clover seed lots tested in 1989 were either downgraded or rejected from certification for failing to meet analytical purity standards, and 1 in 11 of these downgradings or rejections were for excess weed seeds. One weed, field madder (*Sherardia arvensis*) accounted for nearly half of these failures. Weed seed is also one of the major reasons for the failure of ryegrass seed lots to meet certification standards (Rowarth *et al.*, 1990b).

The Official Seed Testing Station, through its computer record system (Scott *et al.*, 1984), has a wealth of analytical purity data, as well as other seed quality information. However, most of this remains locked in files because of various constraints, particularly lack of funds. Thus, apart from the recent white clover and ryegrass surveys, few data are currently available for other species.

Scott (1985) recorded 42 weed species in 39 carrot seed lots and 20 weed species in 50 lettuce seed lots imported in 1980 and 1981. Many of these were of little significance, but 15 of the carrot and 2 of the lettuce seed lots contained species designated undesirable by the New Zealand Agricultural Merchants Federation and the Official Seed Testing Station (Young, 1984). As with white clover (Rowarth *et al.*, 1990a), Californian thistle (*Cirsium arvense*) and Scotch thistle (*C.vulgare*) were the most commonly occurring undesirable weeds.

Cultivar purity

Maintenance of cultivar purity is the major reason for the existence of the seed certification scheme, and cultivar verification involves field inspection, laboratory analysis and field plot testing (Scott and Hampton, 1985). Seed growers are now required to accept full responsibility and accountability for the maintenance of cultivar purity during the growing of certified seed crops, as are seed processors once the crop has been delivered to the processing plant (Hampton and Scott, 1990).

The cultivar purity of New Zealand seed lots is considered high (Scott and Hampton, 1985; Miller and Hampton, 1988) but the proliferation of cultivars (e.g., 34 wheat, 9 barley and 19 perennial ryegrass cultivars are currently eligible for certification, Anon., 1991) may lead to problems, particularly as:

- MAF continues to move from a 'hands on' quality control to "hands off" monitoring (Hampton and Scott, 1990).
- Cultivar descriptions continue to be brief and are often inadequate to allow similar cultivars to be distinguished (Miller and Hampton, 1988).
- Difficulties and deficiencies in the plot testing system continue to become apparent (Scott and Hampton, 1985; Miller and Hampton, 1988).

Miller and Hampton (1988) and Musukwa (1991) have suggested that glasshouse evaluation of breeder and basic seed lots would provide better cultivar quality assurance than the present OECD requirements for plot testing, but to remain within OECD certification, procedures (OECD, 1982) must be adhered to. Electrophoretic cultivar identification (Scott and Hampton, 1985) has yet to be used on a routine basis for any New Zealand produced crops except hybrid maize, but is likely to become a valuable seed certification tool in the future.

Seed moisture

The interaction between seed moisture content (SMC), storage temperature and seed longevity is well established, and there have been many reports of the deleterious effects of unsuitable seed moisture content on the viability of seed (Hill and Johnstone, 1985; Scott, 1985; Hampton and Hill, 1990). Germination losses immediately following harvest still occur because of failure to quickly reduce seed moisture contents to acceptable levels, e.g., the SMC of 14 field dressed prairie grass (*Bromus willdenowii*) seed lots ranged from 11-21% (Hampton, unpub.data). For safe short-term storage under New Zealand ambient conditions, prairie grass seed should be maintained at a SMC of <12%, preferably 10% (Hampton and Bell, 1989). Hampton and Young (1985) found that 16 of 32 perennial ryegrass seed lots with germinations of <80% had suffered heating damage (because of a failure to dry seed to safe seed moisture contents), and 2 perennial ryegrass seed lots with 0% germination from heating damage were recorded during the first half of 1991 (A.A. Johnson, pers. comm.).

Seed vigour

Seed vigour is now accepted as an important seed quality component (Hampton and Coolbear, 1990), but vigour testing on a regular basis is carried out for only a very few species, e.g., the Official Seed Testing Station offers vigour testing for garden peas, maize, onion, prairie grass and crested dogstail (Anon., 1987). The slow uptake of vigour testing is a result of a lack of suitable vigour tests for many species, limitations of many current testing methods, and a reluctance in the market place to utilise vigour information (Hampton and Coolbear, 1990; Hampton and Hill, 1990), although this is changing rapidly in sectors of the horticultural industry.

In New Zealand the importance of optimum populations for yield and quality of garden peas is well established, and since the late 1970s, vigour test results (for conductivity and hollow heart) have been used in conjunction with germination data to provide an expected field emergence value (Hampton and Scott, 1982) from which the grower can calculate a sowing rate to meet a target plant population (e.g., Table 2). In 1981-83, 80% of the 1,155 garden pea seed lots tested had a germination of over 90%, but only 20% of these same lots had an expected field emergence of greater than 90% (Hampton, 1985).

More recently the effects of seed vigour on the performance of herbage seed lots (Table 3) has received attention (Hampton and Hill, 1990), as seed lots of the same chronological age, cultivar, certification class and germination values differ in field emergence and establishment (Wang, 1989), and ability to be stored (Hampton and Bell, 1989; Wang and Hampton, 1991). Seed vigour has also impacted on the success of exported seed lots of prairie grass (Hampton and Bell, 1989) and tall fescue (B. Sampson, pers. comm.), as low vigour lots failed to maintain germination during shipping to overseas markets (Hampton and Hill, 1990).

Meeting Quality Requirements

The quality requirements of the seed certification scheme are documented (Anon., 1991) and failure to meet them can mean rejection from the scheme or downgrading of the crop or seed lot, e.g., failure to meet minimum isolation distances for cross pollinated species, presence of nodding thistle (*Carduus nutans*), yellow gromwell (*Amsinckia calycina*) or wild oat (*Avena fatua, A.sterilis* ssp. *ludoviciana*) at field inspection or laboratory analysis, presence of specified diseases (bacterial blight of peas, loose smut of wheat) at field inspection, *etc*. Rejection or downgrading at laboratory inspection (Rowarth *et al*., 1990a) occurs after all the expenses of producing and cleaning the seed have been incurred, and can drastically alter the returns to the grower (Rolston *et al*., 1990).

Weed seed contamination continues to be a threat to seed exports (Rolston *et al*., 1990; Rowarth *et al*., 1990a). For example, Australia prohibits the entry of any seed containing yellow gromwell, hoary cress,

Table 2. Relationship between germination, vigour and field performance in garden peas (after Hampton and Scott, 1982).

Seedlot	% germination	% EFE	Sowing rate ($g\ m^{-2}$)	% emergence	Plants (m^{-2}) [1]
1	98	90	41	89	147
2	94	79	42	77	143
3	99	79	43	80	150
4	96	65	49	68	147

[1] target was 150 plants m^{-2}

nodding and California thistle, and hemlock (Scott and Hampton, 1985) and is further restricting the amount of dock (*Rumex* spp.) allowed in seed (possibly to a nil tolerance, Rolston *et al.*, 1990); the EC will not import seed lots containing more than 10 *Rumex* seeds in a 20 g sample; the US prohibits the importing of seed containing hoary cress, California thistle or dodder (*Cuscuta* spp.). The New Zealand seed industry must remain competitive on the international market and one of the factors influencing competitiveness is the maintenance of high seed lot quality standards (Rolston *et al.*, 1990).

Poor germination is also affecting the success of seed exports. Germination problems caused by blind seed disease in US tall fescue cultivars grown in New Zealand for multiplication and re-export mean that growers cannot meet the quality requirements previously specified.

Table 3. Field emergence and storage performance of herbage seed lots which germination data indicate are of similar quality.

Seed lot	% germination	% field germination
Trifolium pratense[1]		
1	90	75
2	90	56
3	90	78
4	90	80
Lolium multiflorum[2]		
1	96	90
2	95	67
3	94	78
4	94	87
	Initial % germination	**% germination after 12 months storage**
Trifolium pratense[2]		
1	90	71
2	90	90
3	90	66
4	90	91
Bromus willdenowii[3]		
1	97	97
2	98	85
3	96	95
4	90	74

[1] adapted from Hampton and Hill (1990)
[2] Wang and Hampton (1991); ambient storage
[3] Hampton and Bell (1989); stored at 11.6% SMC and 20°C

While New Zealand farmers and growers generally have access to germination information before purchase if they desire, other users of seed do not. For example, Paul (1989) in a survey of seed sold through food outlets for sprouting purposes found lucerne and red clover seed lots with germinations of less than 60% and contaminated with other seed and inert matter including soil.

New Zealand exports of white clover seed are worth between $10-14 million annually, and there are good prospects for expanding the trade providing high seed quality and competitive prices are maintained (Rowarth *et al.*, 1990a). The introduction of overseas white clover cultivars for multiplication and re-export, and the unique problems of buried seed (Hampton *et al.*, 1987; Miller and Hampton, 1988) have necessitated changes to the certification requirements for 'cultural change' fields (Clifford *et al.*, 1990). The technology is now available to produce seed lots from cultivar change fields which meet all OECD cultivar purity requirements, and in 1989/90, from 255 cultivar change crop entries, only 6 were withdrawn for not meeting specified sowing requirements (Anon., 1991) for crop inspection, and 10 rejected because of contamination at field inspection (Clifford *et al.*, 1990).

For species and cultivars in certification, quality standards for cultivar and physical purity are set by the Seeds Industry Quality Assurance Committee, whose members include MAF, seed trade, seed grower and plant breeding representatives. Quality requirements for seed crops grown for multiplication and re-export are usually specified in the contract signed before sowing the crop, as they often are for crops of proprietary New Zealand cultivars. However, for species, cultivars and crops outside the certification scheme, no set standards exist, and the basic responsibility for maintaining adequate seed quality control rests with the seed producers and industry personnel concerned (Scott and Young, 1984).

New Quality Requirements

For the New Zealand seed industry to utilize the opportunities which currently exist (e.g., Rolston *et al.*, 1990), or are likely to exist in the future (e.g., Hampton *et al.*, 1990), both quality standards and seed quality information must be able to meet changing market requirements. While germination, analytical purity and cultivar purity will continue to be important seed quality components, demand for further information will occur. For example:

a) The number of plantable *Pinus radiata* seedlings raised in New Zealand nurseries is often only 50% of the number of seeds sown, even though laboratory tests may show 90% or better viability (Kartiko, 1990). Seed vigour has been identified as a problem, and vigour test information may enable further differentiation of seed lots (e.g., Table 4), so that the ratio of plantable seedlings to seeds sown is improved.

b) *Acremonium* endophytes of perennial ryegrass have practical and economic implications for animal production (Fletcher *et al.*, 1990), and the recent introduction of 'novel' endophyte in ryegrass cultivars (Rolston *et al.*, 1990) is expected to double seed usage in New Zealand for a decade as farmers renew old ryegrass pastures with 'Endosafe' ryegrasses. Consumers will need information on whether seed lots are endophyte free or contain endophyte, and if the latter, whether the endophyte is viable, particularly if seed has been stored (Rolston *et al.*, 1986).

c) Seed moisture content is considered to be the single most important factor governing longevity of seed, and in red clover, seed moisture content should be reduced to below 10% for storage from one season to the next. However, seed vigour can also influence storage performance. Wang and Hampton (1991) showed that only high vigour seed lots retained their germination in temperate ambient storage for 12 months (see Table 3). Low vigour lots with high germination could not be stored safely under the same conditions for more than 5 months. The decision on the length of time a seed lot can be safely stored will in the future be based on a vigour test result, and not solely the germination test result.

Producing Quality Seed

Assessment of seed quality and treatments to improve seed performance have received considerable research attention, but the emphasis has been almost solely on the end product, the seed as received for quality evaluation. Management has usually concentrated on optimizing seed yields, under the assumption that conditions which promote high seed yield also culminate in conditions which produce the best quality seed. This assumption is not necessarily correct (Hampton,1990). As Gray (1987) pointed out, "it is clearly sensible to examine factors influencing seed quality during production of the seed, and to devise improved systems of production", rather than to incur the added costs of discarding poor quality seed, or attempting to treat lots to improve their overall performance.

Utilizing available technology

One of the advantages of the New Zealand seed industry is the experience and expertise of its researchers (Rolston *et al.*, 1990), but one of the weaknesses is the relatively slow uptake of new technologies (Rolston and Clifford, 1989), resulting in part from reductions in the number of technology transfer personnel (Hampton, 1991). Thus Clifford *et al.* (1990) noted that currently the major limitation to growing high yielding quality white clover seed crops is in making seed multipliers aware of available technology. Programmes such as the "Emerging Technologies" agreement between DSIR Grasslands and Challenge Seed Ltd are the first step towards correcting this deficiency, but more are required.

Some of the seed quality problems encountered, result from failure to utilize long established technologies, for example, the influence of seed moisture content on quality. What proportion of seed growers know the seed moisture of their crop at harvest, monitor it prior to on

Table 4. Correlations between laboratory tests and field performance of *Pinus radiata* seed lots (adapted from Kartiko, 1990).

	Nursery (Rotorua)		Field (Palmerston North)	
Laboratory test [1]	28d field emergence	% plantable seedlings	% normal seedling emergence	% normal seedling survival
% germination	0.56*	0.45	0.53	0.30
vigour [2]	0.78**	0.78**	0.87*	0.98**

[1] at Palmerston North

[2] 2 d controlled deterioration (45°C and 20% SMC)

farm storage, or dry seed correctly before storage? Is seed moisture content always known before packaging horticultural seed in sealed aluminium foil bags? Attention to well known seed technology principles and practices could prevent quality losses.

The need for further information

Many seed associated problems, eg poor and/or uneven establishment, reduced quality and/or yield of product, storage failure *etc.* have now been linked with seed vigour (Hampton and Coolbear, 1990), a reciprocal of the deterioration process involved with seed ageing. Low vigour seed lots may have high germination (e.g., Table 3), but be physiologically older because more deterioration has occurred. Losses in seed vigour can begin prior to harvest, and are then exacerbated by events at harvest, and during handling and processing, as cell membrane integrity becomes damaged for physiological and/or physical reasons (Powell, 1988; Hampton, 1990). Questions that need answering conclusively include:

- could enhanced seed vigour become a primary plant breeding objective?
- are nutrient requirements for seed quality including vigour necessarily the same as those for seed yield?
- does position on the mother plant and crop morphology affect seed vigour?
- can changing the crop environment improve seed vigour?
- what effects do seed moisture content, time and method of harvest, time and method of drying, and processing have on seed vigour?

Quick broad answers are "yes", "not necessarily", "yes", "yes" and "lots"! However, as yet there is little information as to the precise effects of present production practices on seed vigour (see Hampton, 1990). Some preliminary work with New Zealand garden peas (Tables 5, 6, 7) suggests that pod position in the canopy, region of production and time of harvest can all influence pea seed vigour, and that therefore changes in production practice could improve seed lot quality. However, there is a need for research to determine which current production practices are responsible for reductions in seed vigour.

Conclusion

It has not been possible in this review to cover all aspects of the topic, or all species grown for seed in New Zealand. It could also be said that there has been a concentration on the negative, and not the positive. However, that was deliberate. New Zealand does have an international reputation for quality seed, but to remain competitive, that reputation must be maintained (Rolston

Table 5. Effect of pod position in the canopy on hollow heart and conductivity in hand harvested garden peas cv. Princess[1].

Pod position	% hollow heart	conductivity µS.cm^{-1}g^{-1}seed
top	12.5 a[2]	12.3 a
middle	9.0 c	11.6 a
bottom	11.5 ab	10.3 b
% cv	8.4	7.8

[1] Castillo and Hampton, unpublished data
[2] Means within columns followed by different letters denote means that are significantly different at the P=0.05 level.

Table 6. Effect of region of production and season on the percentage of seedlots in high vigour categories in garden pea cv. Small Sieve Freezer[1].

Region/Season	% hollow heart	conductivity µS.cm^{-1}g^{-1}seed
Wairarapa		
1981	71	16
1982	65	7
1983	76	8
Canterbury		
1981	93	14
1982	61	20
1983	95	34

[1] data adapted from Hampton (1985)

Table 7. Effect of seed moisture content at harvest on seed quality of combine harvested garden peas cv. Pania[1].

% seed moisture content	% hollow heart	conductivity µS.cm^{-1}.g^{-1}seed	% germination
40	8	30	74
25	11	18	91
15	19	21	95

[1] Castillo and Hampton, unpublished data

et al., 1990). The danger is that complacency will lead to a failure to maintain the present high standards.

The use of more precise information on seed quality is likely to become more commonplace as farmer and grower awareness continues to improve and the market becomes even more competitive for the seed producer and exporter (Hampton and Hill, 1990). The New Zealand seed industry must have in place the technologies and techniques to produce the quality seed the market will demand.

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