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Herbage seed lots: are germination data sufficient?

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Abstract

Herbage seed lots of the same chronological age, certification class and germination values often differ in performance in the field, in storage, or both. These performance differences are ascribed to another seed quality factor, seed vigour. Vigour differences have been shown *to* occur in New Zealand seed lots of ***Trifolium repens, T. pratense, Medicago sativa, Bromus willdenowii, Cynosurus cristatus*** and ***Festuca*** spp., and are highly likely to occur in all other herbage species. This review of vigour in herbage seed lots discusses the concept, its possible causes, the implications for sowing, storage and export of seed, and how seed lot vigour information might be used by the farmer, seed store manager and seed marketer.

Keywords seed vigour, field emergence, storage, export, herbage seed, germination

Germination and all that!

Germination testing is designed to provide information about the-planting value of a seed lot, and remains the principle and internationally accepted criterion for seed viability. A germination test result less than an accepted standard (e.g. below 90%) indicates that the quality of the seed lot is suspect, and that there may be future problems with field emergence or ability to be stored (Hampton & Coolbear 1990).

However, performance differences may occur between seed lots which the germination test indicates are of similar high quality (e.g. Table 1). Therefore the germination test seems adequate to indicate quality attributes of the seed **except** at high germination values (Roberts 1984) when, because of the nature of the normal distribution on which the seed survival curve is based, a small difference in percentage germination represents a large difference in the progress of seed deterioration (Ellis & Roberts 1980).

The reason for performance differences between high quality seed lots is ascribed to seed vigour, a further component of seed quality, and in these circumstances, vigour becomes important and vigour testing necessary (Hampton & Coolbear 1990).

What is seed vigour?

Seed vigour is not a single measurable property like germination, but a concept describing several seed performance associated characteristics (Perry 1981). It can encompass potential seed perfomance both in the field and in storage (Hampton & Coolbear 1990) and is defined as "the sum total of those properties of the seed which determine the level of activity and performance of the seed or seed lot during germination and seedling emergence. Seeds which perform well are termed high vigour seeds, and those which perform poorly are called low vigour seeds" (ISTA 1981).

Seed vigour can be considered a reciprocal of the deteriorative processes involved with seed aging, both pre- and post-harvest, in that vigour decreases as the level of deterioration increases. Seed deterioration begins from the time seeds attain physiological maturity @e-harvest), and its time course may range from a few days to many years depending upon factors such as genetic constitution, the environment, seed moisture content and physical damage. Biochemical changes occur, following a generalised sequence, and involving changes in solute leakage, enzyme activity, respiration and ATP content, protein and DNA synthesis, the- chemical content of the seed, and genetic changes. The factors influencing these biochemical changes have been recently reviewed (Powell 1988).

The consequences of seed deterioration (physiological aging) are a progressive reduction in performance capabilities, such as reduced germination rate, lowered germination, and consequently increases in abnormal seedlings and dead seed. However, loss of vigour often precedes loss of germination (ISTA 1981; Wang & Hampton 1990), so that although two seed lots may have similarly high germination values, one seed lot can be physiologically older than the other (i.e. more deterioration has occured); thus its vigour is lower, and it cannot perform as well as the high vigour lot.

Seed vigour and herbage species

The association between seed lot vigour and performance in herbage species is not a new one. Foy (1934) linked differences in germination between

Table 1 Performance of herbage seed lots which germination data indicate are of similar quality.

A. Field emergence

Seed lots	Trifolium pratense[1] 1	2	3	4	Lolium multiflorum[2] 1	2	3	4	5
% germination	90	90	90	90	96	95	94	92	94
% field emergence	76	56	78	80	90	67	78	79	87

B. Storage

Seed lots	Trifolium incarnatum[3] 1	2	3	4	Festuca arundinacea[3] 1	2	3	4
initial germination	90	90	94	88	90	91	90	88
germination after) 6 m	90	90	92	76	91	90	84	74
storage for) 12 m	92	89	84	48	90	73	58	24

[1] autumn sown in replicated adjacent rows, Palmerston North, New Zealand (Wang & Hampton 1989)
[2] spring sown in replicated adjacent rows, Aberdeen, Scotland (adapted from Naylor 1981)
[3] stored in non-conditioned warehouse, Mississippi, USA (adapted from Delouche & Baskin 1973)

Festuca rubra seed lots after shipment from NZ to the UK to differences in seed "vitality" (vigour). However, later work tended to attribute performance differences between herbage seed lots of similar germination capacity to seed size (e.g. Charlton 1989), and strong correlations between this quality component and germination rate, emergence and seedling growth have been recorded. Many inconsistencies in this relationship have also been reported (Scott & Hampton 1985; Charlton 1989; Wang & Hampton 1989), and it is now generally accepted that the causes of vigour differences in many species are physiological rather than directly physical, although the latter may influence the former.

Seed vigour differences have now been reported in both herbage legumes and grasses (e.g. Table 2), although in New Zealand, the only species yet surveyed is *Bromus willdenowii,* in which Scott & Hampton (1985) found that from 49 certified seed lots harvested-in 1.984, only 23 could be classified as being of 'high' vigour.

The implications of seed vigour

For sowing

When seed lots have a range of different germination values, the correlation between germination and field emergence is often good. However, when seed lot germination values are all high, germination may be only poorly related to field emergence (e.g. Table 3), and only when seed bed and environmental conditions approach the optimum for the species will the relationship be strong (eg, 13 November sowing, Table 3). Because a vigour test can differentiate potential seed performance more sensitively, vigour test results can be more strongly related to field emergence than germination test results (Table 3).

Wang (1989) found significant differences in field emergence for six 'Grasslands Pawera' red clover seed lots at 7 out of 8 sowings at the same site, and data for 3 of the autumn sowings are provided in Table 4. For all sowings, the low vigour seed lots had a lower and slower emergence than high vigour seed lots. Low vigour seed lots also produced smaller

Table 2 Germination data for herbage seed lots before and after vigour testing by the accelerated aging (AA) method'

		Seed lot 1	2	3	4
Medicago sativa cv Wairau	initial % germination	90	94	93	91
	% germination after AA[2]	43	76	31	76
Trifolium repens cv G. Huia	initial % germination	91	91	90	94
	% germination after AA*	35	15	56	31
Trifolium pratense cv G. Pawera	initial % germination	90	90	90	92
	% germination after AA*	63	7	42	60
Bromus willdenowii cv G. Matua	initial % germination	97	98	90	
	% germination after AA'	94	52	82	

[1] Data adapted from Hampton & Bell (1989); Wang (1989) Wang & Hampton (1989)
[2] 72 h at 40 ± 0.5 °C and 96% RH
[3] 96 h at 45 ± 0.5 °C and 100% RH

Table 3 Relationship between field emergence of 6 'Grasslands Pawera' red clover seed lots and laboratory quality assessments (data adapted from Wane. 1989).

Sowing date	Germination test	Accelerated aging'	Controlled deterioration'
23 Sept	0.62	0.88 **	0.96 **
18 Oct	0.39	0.71	0.74
13 Nov	0.93**	0.59	0.83 *
21 Mar	0.43	0.93 **	0.94 **
5 Apr	0.41	0.99 **	0.94 **
20 Apr	0.57	0.88 **	0.88 *
9 May	0.51	0.70	0.79 *
20 May	0.19	0.78 •	0.69

[1] vigour tests based on germination after inducing rapid aging (AA = 48 h at 40 ± 0.5°C and 96% RH; CD = 24 h at 45 ± 0.5°C and 16% SMC)
[2] correlation coefficients (r). * P < 0.05, ** P < 0.01

Table 4 Field emergence and emergence rate for four Grasslands Pawera red clover seed lots sown at the same site in autumn 1989 (adapted from Wang 1989).

Sowing date		21 March		20 April		20 May	
		F.e.[1]	E.r[2]	F.e[1]	E.r.[2]	F.e.[1]	E.r[2]
Seed lot'	1	56b[3]	8.7b	65c	7.8c	58ab	6.3c
	2	76a	11.6a	77b	10.7a	67ab	7.7b
	3	56b	7.9b	68c	8.3b	57b	6.2c
	4	78a	11.9a	89a	10.9a	79a	10.4a

[1] % field emergence
[2] emergence rate (Wang 1989)
[3] figures within any column followed by the same letter do not differ significantly at P < 0.05
[4] seed lots 1 and 3 = 'low' vigour, seed lots 2 and 4 = 'high' vigour

seedlings, and Wang & Hampton (1989) reported that seedling dry weight at 5 weeks after 3 autumn sowings was 23-28% lower from a low vigour Pawera seed lot than from a high vigour lot.

As yet data for seed lot performance after sowing in herbage species are limited, and it could be argued that the fact that vigour can influence performance, particularly with autumn sowings, is of no practical significance, because farmers usually use sowing rates far higher than-are-actually-needed&harlton-et al. (1986) and Hampton et al. (1987) have reported the negative influence of low autumn temperatures on germination rate in many New Zealand herbage species. If this is further complicated by poor seed vigour, the ability to establish, produce dry matter and survive, particularly in a competitive multispecies sward, becomes extremely important (Wang & Hampton 1989). Further work is required to confirm this in both grass and legume species.

For storage

Recent studies have demonstrated that high vigour seed lots of *Cynosurus cristatus* (Clark 1982), *B. willdenowii* (Hampton & Bell 1989) and *T. pratense* (Wang & Hampton 1990) have a better storage potential than low vigour lots. This is because the ability to withstand environmental stresses is greater in high vigour lots, so that when, for example, seed moisture content is too high (e.g. Table 5) or storage temperature is beyond safe limits (Clark 1982; Wang & Hampton 1990), high vigour seed lots will retain their germination longer. Data are not yet available for other New Zealand herbage species, but considering the evidence from other graminae and legumes, other commonly grown herbage species will probably react in the same. manner.

The interaction between storage temperature, seed moisture content and seed longevity is well established, and there have been many reports of the deleterious effects of unsuitable storage conditions on the viability of herbage seed (Hampton & Bell 1989). Recent evidence (Clark 1982; Hampton & Bell 1989; Wang & Hampton 1990) suggests that the commonly accepted "safe" moisture contents of 13-14% for ambient storage of grasses, and 8-10% for herbage legumes do not necessarily apply to all species — for example, *B. willdenowii, F. rubra* and C. *cristatus* should be dried to around 10% seed

Table 5 Effect of seed lot moisture content (SMC) and vigour on germination of crested dogstail after storage at 20°C for 18 months (adapted from Clark 1982).

Months of storage		0	3	6	12	18
I I .4% SMC	high vigour lot	96	95	95	94	93
	low vigour lot	95	90	85	85	82
14.0% SMC	high vigour lot	96	91	58	4	0
	low vigour lot	95	52	28	0	0

moisture for safe storage (Clark 1982; Hampton & Bell 1989). But even at these lower moisture contents, seed lots will perform differently depending upon their vigour (Wang & Hampton 1990). Therefore, vigour test results should be an important management tool for a seed store manager.

For export

Problems with germination decline of high germinating seed lots 'after shipping to overseas markets have been reported for *F. rubra, C. cristatus* and *B. willdenowii* (Foy 1934; Clark 1982; Hampton & Bell 1989), but these problems occurred only with some lots in the shipment. Exported seed lots may be exposed to several hazards while in transit, particularly fluctuations in temperature and humidity in containers either in a ship's hold or on deck, i.e. the seed lots undergo environmental stress. High vigour seed lots are more likely to be able to withstand these stresses than low vigour lots, and Scott & Hampton (1985) and Hampton & Bell (1989) recommended vigour testing to determine the suitability of seed lots for export.

What causes vigour differences?

Perry (I 981) listed known causes of variation in seed vigour as 'genetic constitution, environment and nutrition of the mother plant, stage of maturity at harvest, seed size, mechanical integrity, deterioration and aging, and pathogens'. More recent evidence points to physiological causes, and the integrity of cell membranes, as determined by deteriorative biochemical changes and/or physical disruption, can therefore be considered to be a fundamental cause of differences in seed vigour (Powell 1988).

Charlton (1989) found that seed lot performance (germination rate) of parent lines of *Lotus uliginosus* cv 'Grasslands Maku' was associated with seed size, in that [illegible] lower thousand seed weight (TSW) tended to have lower germination rates. However, he also noted that one parent line was exceptionally slow to germinate despite having the largest seeds. This inconsistency in the seed size/quality relationship is common. Very often, larger seeds are more vigorous because they have larger food reserves, but seed lots with large seed can also be of low vigour, and vice versa; for example Wang & Hampton (1990) found that a seed lot of Pawera with a TSW of 3.2 g was of higher vigour and consistently outperformed another lot with a TSW of 4.1 g.

Obviously, physical damage can influence physiological damage. Harvesting seed at unsuitable moisture contents, or using incorrect processing techniques, can rupture the seed coat and damage the embryo; in its severest forms this results in dead seeds or abnormal seedlings. But often this damage may be more subtle, on a cellular level, and therefore not visible externally and unlikely to be detected in a germination test. Any factor that increases the rate of seed deterioration will contribute to loss of seed vigour .

The effects of seed production, harvest and processing practices on New Zealand herbage seed quality urgently require further investigation. Dourado (1989) suggested that allowing seeds of *B. willdenowii* to dry naturally before threshing, rather than placing threshed seed immediately in a dryer, improved its quality. There is limited evidence to support this (Table 6), in that *B. willdenowii* seed which was either direct combined or swathed, but left to air dry, rather than dried with heated air, had greater vigour. Further work (Hampton & Rolston unpub. data) showed that the temperature of the heated air, (from 25 to 43°C) did not further affect vigour .

At present we know that seed vigour differences exist within herbage species, and that there are techniques for assessing these differences, but there is little information as to how they occur.

Interpreting vigour information

Rapid aging vigour tests such as accelerated aging (AA) and controlled deterioration (CD) do not give an absolute vigour value, but are designed to rank seed lots for potential planting and storage value (Hampton & Coolbear 1990). The germination test result after rapid aging indicates whether the seed

Table 6 Effect of harvest method and drying method of germination and vigour of *Bromus willdenowii* cv. G. Matua (unpublished data of Hampton & Rolston).

	Treatment	Moisture content of sample	% germination initial	% germination after AA
1.	Direct combine 45% SMC	20%	93	66
	then hot air (30°C) dried	12%	93	66
2.	Direct combine 45% SMC,			
	cool air dried to 39% SMC	39%	91	90
	then hot air (30°C) dried	12%	92	85
3.	Swath 45% SMC, combine	15%	92	56
	30% SMC, then hot air (30°C) dried	11%	95	53
4.	Swath 45% SMC, combine 22% SMC,	22%	98	91
	then unheated forced air dried	13%	98	89
		11%	97	83

lot is of high or low vigour, i.e. if the germination remains high after such treatment, the seed lot is of high vigour, whereas if the germination is markedly reduced, the seed is of low vigour. Because results cannot be meaningfully expressed as a percentage, they are often reported in terms of vigour grades (Hampton 1985).

Seed for sowing

The first step should always be to check the germination and ensure that it is of acceptable quality (e.g. 90% or greater). If seed is to be sown early in autumn (March) or late in spring (October) when seed bed conditions and soil temperatures are likely to be more favourable for rapid establishment, seed lot vigour may be of little consequence. This has yet to be confirmed. Seed lot vigour will become important when environmental stresses occur at sowing (e.g. as soil temperatures cool in autumn), particularly in those species which are more temperature sensitive than *Lolium perenne* and *Trifolium repens* (Charlton *et al.* 1986; Hampton *et al.* 1987), and also when species are sown in mixtures and seedling competition becomes a factor. If a buyer has a choice between several seed lots with similar high germinations, it would be advantageous to know the vigour status of each seed lot before choosing.

Seed for storage

A germination test result of less than 85-90% (depending on the species) will indicate that there are prdblems with the lot and that it is unlikely to store well. Seed lots with high germination but low vigour can be safety stored for more than 4-5 months only under conditioned storage (low temperature 5-10°C and low SMC < 10%). If these conditions are not available, seed lots should be sold within 2-4 months of harvest. High vigour seed lots should retain their germination under ambient storage conditions, provided that the seed moisture is at the appropriate level for the species concerned.

Seed marketing

Seed firms have been understandably cautious in using seed vigour information in marketing and promotion, because for many, the concept is new and unproven. However, in competitive market places overseas, some firms use vigour information as a marketing strategy (though not for herbage species). The majority continue to refrain from using such information for advertising purposes, realising the dangers of misuse of information, such as making claims for potential seed performance which do not eventuate in the field (Hampton & Coolbear 1990). There is also a very negative view of seed vigour by parts of the seed trade who are concerned with the problems of selling low vigour seed. After all, in the absence of any other information, a seed lot with high germination may be sold readily irrespective of its vigour rating.

Conclusion

The use of more precise information on seed quality is likely to become more commonplace as farmer awareness continues to improve and the market becomes even more competitive for the seed producer. No one can afford to be complacent about seed quality, and although the work with herbage seed vigour is in many ways still in its infancy, it is a very important concept which should not continue to be ignored.

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