Herbage Seed Lot Vigour - Do Problems Start with Seed Production?

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ABSTRACT

Herbage seed lots often differ in vigour, reducing establishment and dry matter production, performance after storage, and ability to be exported. Cell membrane integrity, determined by deteriorative biochemical changes and/or physical disruption can be considered to be a fundamental cause of differences in seed vigour. Factors possibly influencing cell membrane integrity, and hence the seed aging process, during herbage seed production are discussed, and the need for research to determine which current production practices reduce seed lot vigour emphasised.

Additional index words: **herbage grasses, herbage legumes, seed quality, seed establishment, seed storage, production practices.**

INTRODUCTION

Herbage seed lots which a germination test indicates are of similar high quality may perform differently in the field (Table 1) or during storage (Table 2). The reason for such performance differences is ascribed to seed vigour (Hampton and Coolbear, 1990), i.e. seed lots which emerge or store poorly relative to their laboratory germination are said to be of low vigour. Seed vigour is not a single measurable property like germination, but a concept describing several seed performance associated characteristics (Perry, 1981) which can encompass potential seed performance both in the field and in storage (Hampton and Coolbear, 1990). It can be considered a reciprocal of the deterioration 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 (pre-harvest) and its time course may run from a few days to many years depending upon the effects of factors such as genetic constitution, the environment, seed moisture content and physical damage on cell membrane integrity. The biochemical changes which occur during this physiological aging (Powell, 1988) produce 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 (Hampton and Hill, 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 occurred), so that its vigour is lower, and it cannot perform as well as the high vigour lot (Tables 1 and 2).

Table 1. Field emergence performance of herbage seed lots which germination data indicate are of similar quality.

	Trifolium pratense[1]			
Seed Lot	1	2	3	4
% germination	90	90	90	90
% field emergence	76	56	78	80

	Lolium multiflorum[2]				
Seed Lot	1	2	3	4	5
% germination	96	95	94	92	94
% field emergence	90	67	78	79	87

[1]autumn sown in replicated adjacent rows, Palmerston North, New Zealand (Wang and Hampton, 1989).
[2]spring sown in replicated adjacent rows, Aberdeen, UK (adapted from Naylor, 1981).

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Table 2. Storage performance of herbage seed lots which germination data indicate are of similar quality.

Legumes	*Trifolium incarnatum*[1]				*Trifolium pratense*[2]			
Seed lot	1	2	3	4	1	2	3	4
Initial % germination	90	90	94	88	90	90	90	90
% germination) 6 m	90	90	92	76	74	87	76	86
after storage for) 12 m	92	89	84	48	71	90	66	91
Grasses	*Festuca arundinacea*[1]				*Bromus willdenowii*[3]			
Seed lot	1	2	3	4	1	2	3	4
Initial % germination	90	91	90	88	97	98	96	90
% germination) 6 m	91	90	84	74	98	90	96	88
after storage for) 12 m	90	73	58	24	97	85	95	74

[1]stored in non-conditioned warehouse, Mississippi, USA (adapted from Delouche and Baskin, 1973).
[2]ambient storage, Palmerston North, NZ (adapted from Wang and Hampton, 1991; data are for 7 and 11 months)
[3]stored at 11.6% SMC and 20°C (adapted from Hampton and Bell, 1989; Hampton unpubl. data).

IS SEED VIGOUR IMPORTANT IN HERBAGE SPECIES?

Seed vigour differences have now been reported in both herbage legumes and grasses (Hampton and Hill, 1990), whereby seed lots of the same cultivar, chronological age, certification class and germination value differ significantly in performance.

a) **For sowing**

It could be argued that seed lot vigour is of no practical significance when sowing herbage species because farmers usually use sowing rates far higher than are actually needed (Hampton and Hill, 1990). However, Wang and Hampton (1989) showed that the dry weight of *Trifolium pratense* seedlings from a low vigour seed lot was 25% lower than that from a high vigour seed lot at each of two autumn sowings, and if the negative influence of low autumn temperatures on germination rate (Hampton, Charlton, Bell and Scott, 1987) 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 and Hampton, 1989). Similarly, Marshall and Naylor (1984) reported that seed quality in grasses affected field emergence and subsequent stand establishment, and Hall and Wiesner (1990) found that field emergence and forage production were significantly correlated with seed lot vigour in *Bromus biebersteinnii* Roeem. and Schult., (Table 3). In one trial, the annual dry matter production difference between two seed lots which differed only in their vigour status was 1.65 t.ha^{-1} or 30% (seed lots 863 and 862, Table 3). Hall and Wiesner (1990) concluded that differences in seed vigour affected first year forage yield and also that compensating for low seed viability did not improve field performance.

Table 3. Effect of seed lot vigour on seedling emergence and first year forage yield in *Bromus biebersteinnii*[1]

Seed lot	**initial % germination**	**% germination after AA[2]**	**seedlings per metre**	**forage yield t.ha^{-1}**
863	94	76	35	5.58
864	92	64	55	4.21
865	90	35	38	4.15
861	96	33	32	4.09
862	94	58	35	3.93

[1]adapted from Hall and Wiesner (1990) to exclude seedlots with germination <90%; seedlings per metre do not differ significantly, but seedlot 863 significantly different at $P < 0.05$ for forage yield.
[2]accelerated aging vigour test.

b) **For storage**

Recent studies have demonstrated that high vigour seed lots of *Cynosurus cristatus*, *Bromus willdenowii* and *Trifolium pratense* have a better storage potential than low vigour lots because the ability to withstand environmental stress is greater in high vigour lots (Clark, 1982; Hampton and Bell, 1989; Wang and Hampton, 1991), i.e. when moisture content is too high or storage temperature beyond safe limits, high vigour seed lots will retain their germination for longer (Table 2). Even at seed moisture contents lower than the commonly accepted 'safe' levels (<10%), seed lots will still perform differently depending upon their vigour (Wang and Hampton, 1991).

c) **For export**

Problems with germination decline of high germinating lots after shipping to overseas markets have been reported (Foy, 1934; Clark, 1982; Hampton and Bell, 1989). Seed lots are often exposed to environmental hazards while in transit, particularly fluctuations in temperature and humidity in containers within a ship's hold or on deck, and high vigour seed lots are more likely to be able to withstand these environmental stresses than low vigour lots (Hampton and Hill, 1990).

The association between seed lot vigour and performance in herbage species is hardly a new one. Foy (1934) for example, linked differences in germination between *Festuca rubra* seed lots after shipment from New Zealand to U.K. to differences in seed 'vitality' (vigour). However, later work often tended to attribute performance differences between herbage seed lots of similar germination capacity to seed size, and the concept of herbage seed vigour was ignored; only recently has its importance been recognised (Hampton and Hill, 1990).

PRODUCTION TO AVOID LOW VIGOUR SEED?

It is now generally accepted that causes of vigour differences in many species are physiological rather than directly physical (although the latter may influence the former), and that cell membrane integrity, 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, 1985, 1988). Assessment of seed vigour 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. Yet surely the initial goal should be to understand enough about the variables which limit any aspect of seed performance to be able to avoid vigour loss through the production system (Hampton and Coolbear, 1990). As Gray (1987) pointed out, "it is clearly sensible to examine the factors influencing seed quality during production of the seed and to improve systems of production", rather than incur the added costs of discarding poor vigour seed, or attempting to treat lots to improve their overall performance.

* why should *T. pratense* seed lots of the same cultivar, certification class and chronological age differ in their vigour (Wang and Hampton, 1989)?
* why should a high thousand seed weight *Lotus uliginosus* seed lot perform more poorly than other seed lots with lower thousand seed weight (Charlton, 1989)?
* why should method of seed drying affect the vigour of *Bromus willdenowii* seed lots (Hampton and Hill, 1990)?
* why should *Trifolium repens* and *Medicago sativa* seed lots with similar high germination values differ in their ability to withstand environmental stress (Wang, 1989)?

A part answer could be that for some reason, the low vigour seed lots are physiologically older, but is it possible to explain why? What factors influence cell membrane integrity and hence aging during seed production?

a) **Genetic constitution**

Selection for increased thousand seed weight has often led to improved germination rate, emergence, seedling growth and yield (Hampton, 1986; Charlton, 1989) and in New Zealand, a thousand seed weight certification standard exists for a tetraploid cultivar of *Lolium multiflorum* (Hampton, 1986). However, many inconsistencies in this type of relationship have also been reported (Hampton and Hill, 1990) so that although larger seeds may be more vigorous because they have larger food reserves, seed lots with large seeds can also be of low vigour, and vice versa; for example Wang and Hampton (1991) found that a seed lot of *T. pratense* with a thousand seed weight of 3.2 g was of higher vigour and consistently out-performed another lot of the same cultivar with a thousand seed weight of 4.1 g.

Plant breeders have often inadvertently selected for increased seed vigour (Copeland and McDonald, 1985), but there is a need for more specific selection where enhanced seed vigour is a primary objective. For example, selection in herbage legumes for seed coats which are 'delayed - permeable' (Kuo, 1989), i.e. seeds which are not hard, but whose imbibition is initially delayed, so that they are less susceptible to cycles of wetting and drying prior to harvest, and absorb moisture more slowly from the ambient atmosphere during open storage. Genotypic influences on factors affecting cell membrane integrity (such as imbibition rate) need to be further investigated.

b) **Nutrition of the mother plant**

Bean (1980) reported that seed nitrogen content was significantly correlated with germination rate and seedling dry weight in *Lolium perenne*, and in most grasses, increasing

nitrogen application can increase thousand seed weight. However, in peas, seed vigour was reduced following a high nitrogen regime (Browning and George, 1981), although if high nitrogen was combined with medium phosphorous supply, seed vigour was improved (Hadavizadeh and George, 1988). Can increasing seed protein and phospholipid content improve cell membrane integrity or delay degradation?

At present, herbage seed crop fertiliser requirements tend to be managed for optimising seed yield, rather than seed quality. It is also generally agreed that when soil fertility becomes limiting, plants respond by producing less seed rather than reducing seed quality *per se* (Hampton, 1990). Is this assumption correct? What effects do nutrients have on herbage seed vigour? Is it perhaps time to start considering nutrient requirements for seed quality rather than just quantity?

c) **Position on the mother plant**

The influence of seed position on seed quality has been investigated in many species and components such as seed size, embryo size and germination are known to vary, depending on such factors as assimilate supply, photosynthetic activity, plant morphology, maturity and the micro-environment (Bean, 1980; Hampton, 1990). Position in the canopy affects vigour in large seeded legumes, but conflicting data have been presented (Hampton, 1990), pointing to the need for a more precise understanding of environmental effects on seed vigour.

d) **Environment**

The importance of the climatic components of the environment are recognised for seed production (Delouche, 1980), yet very often seed is not produced in areas with highly favourable environments. Bean (1980) showed that thousand seed weight, germination rate, seed nitrogen content and mean seedling dry weight differed significantly depending upon where *L. perenne* seed lots had been grown, and Hampton (1990) demonstrated the effect of site of production on seed vigour of garden peas. Recent results from experiments with large seeded legumes (Adam *et al.*, 1989; Hampton, 1990) have shown that the assumption that conditions which promote high seed yield also culminate in conditions which produce the best seed quality if not necessarily correct.

If a crop could be managed to avoid prolonged exposure to adverse environmental conditions during seed maturation, higher vigour seed may be produced. For example, in an experiment where *T. repens* seed lots were exposed to wetting and drying cycles (from 20% SMC to 8.5% SMC and back to 20% SMC) seed lot deterioration was rapidly induced, as evidenced by a decline in germination, and increase in abnormal seedlings and dead seeds (Table 4). An ideal situation would be to have a seed crop where the majority of seeds were of the same physiological status and maturity, growing in an environment which did not favour deterioration during seed development, maturation and the pre-harvest period (Hampton, 1990).

Table 4. Effect of a wetting and drying cycle on germination of *Trifolium repens* cv. Grasslands Huia[1].

	% normal seedlings[2]	% abnormal seedlings	% hard seed	% dead seed
initial germination test	95	1	3	1
germination after first wetting[3]	92	5	1	2
germination after 24h drying[4]	86	11	0	3
germination after second wetting	87	11	1	1
germination after 24h drying	86	8	2	4
germination after third wetting	77	16	2	6
germination after 24h drying	79	15	1	5

[1]from Miller (1988)
[2]data are the mean of two seed lots
[3]wet to 20% seed moisture content
[4]dried to 8.5% seed moisture content

e) **Maturity, harvest and processing**

Poor seed vigour is commonly associated with aging following delayed harvest because of inclement weather (e.g. Table 4), such delays subjecting the seed to field deterioration (weathering) and/or mechanical abuse during the harvesting process (Matthews and Powell, 1986). Harvesting seed at unsuitable moisture contents, or using incorrect harvesting techniques can rupture the seed coat and damage the embryo. In its severest form this results in dead seeds or abnormal seedlings. For example, a survey of New Zealand white clover seed growers in 1985/86 and 1986/87 found that 73% of those who used a desiccant produced seed lots with <80% germination (>10% abnormal seedlings) compared with 43% of those who did not use

a desiccant (Miller, 1988). Similarly, 80% of growers who did not adjust combine settings or monitor results produced low germinating seed lots, compared with 22% of growers who constantly monitored their results. Grower opinion was that incorrect combine settings and condition of the crop at harvest were the factors most likely to cause seed damage. Often such damage is more subtle, at 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 (e.g. Table 4) will contribute to loss of seed vigour.

By physiological maturity seeds have reached maximum vigour but still have seed moisture contents ranging from 40-65% depending on the species. The decision as to when to harvest is usually based on allowing seeds to attain full viability and to dry to a moisture content which does not produce physically damaged seed, but which is not so low that seed shedding has occurred. However, does the seed moisture content which allows 'safe' harvesting necessarily produce the highest vigour seed? What effect does direct versus swath harvesting have on seed vigour? Does artificial drying affect seed vigour? Dourado (1989) suggested that allowing seeds of *B. willdenowii* to dry naturally prior to threshing, rather than placing threshed seed immediately in a dryer, improved its quality and Hampton and Hill (1990) reported that prairie grass seed which was left to air dry, rather than dried with heated air, had similar germination but greater vigour (Table 5). The effects of harvest timing, harvest method and post harvest processing on the herbage seed aging process require investigation.

CONCLUSION

Most of the factors considered to influence seed vigour (Perry, 1981) can be directly or indirectly linked back to cell membrane integrity, deterioration and aging, and it should be possible to change seed production practices to improve the vigour of seed lots. However, as yet there is little information as to the precise effects of present production practices on herbage seed vigour, and much research is required. Perhaps the first step should be to evaluate the effects of mechanised processes (harvesting, drying, cleaning) on seed lot vigour, because if germination impairment due to physical damage is regularly detected (Scott and Hampton, 1985), damage at the cellular level must also be occurring. Techniques exist for detecting low vigour (Hampton and Hill, 1990), but the goal for the seed grower should be to avoid the production of low vigour seed.

Table 5. Effect of harvest method and drying method on germination and vigour of *Bromus willdenowii* cv. Grasslands Matua[1]

	Treatment	Moisture content of sample	% germination initial	% germination after AA[2]
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, combined 22% SMC,	22%	98	91
	then unheated forced air dried	13%	98	89
		11%	97	83

[1]from Hampton and Hill (1990)
[2] accelerated aging test for vigour

REFERENCES

1. Adam, N.M., McDonald, M.B. Jr. and Henderlong, P.R. 1989. The influence of seed position, planting and harvesting dates on soybean seed quality. *Seed Science and Technology* 17: 143-152.

2. Bean, E.W. 1980. Factors affecting the quality of herbage seeds. In: Seed Production (ed. P.D. Hebblethwaite), pp. 593-604, Butterworths, London, UK.

3. Browning, T.H. and George, R.A.T. 1981. The effects of mother plant nitrogen and phosphorous nutrition on hollow heart and bleaching of pea (*Pisum sativum* L.) seed. *Journal of Experimental Botany* 32: 1085-1090.

4. Charlton, J.F.L. 1989. Temperature effects on germination of 'Grasslands Maku' lotus and other experimental lotus selections. *Proceedings of the New Zealand Grassland Association* 50: 197-201.

5. Clark, S.M. 1982. An evaluation of seed quality in crested dogstail in relation to storability. *Seed Science and Technology* 10: 517-526.

6. Copeland, L.O. and McDonald, M.B. Jr. 1985. Principles of Seed Science and Technology (2nd edition), Burgess Publishing Co., Minnesota, USA, 321 pp.

7. Delouche, J.C. 1980. Environmental effects on seed development and seed quality. *HortScience* 15: 775-780.

8. Delouche, J.C. and Baskin, C.C. 1973. Accelerated aging techniques for predicting the relative storability of seed lots. *Seed Science and Technology* 1: 427-452.

9. Dourado, A.M. 1989. The effect of seed size, method of harvest and accelerated aging on germination of 'Grasslands Matua' prairie grass (*Bromus catharticus*). *Seed Science and Technology* 17: 283-288.

10. Foy, N.R. 1934. Deterioration problems in New Zealand chewings fescue. *New Zealand Journal of Agriculture* 49: 10-24.

11. Gray, D. 1987. The potential of plant growth regulators for improving vegetable seed quality. In: Growth Regulators and Seeds, Monograph 15, (ed. N.J. Pinfield, M. Black), pp 93-105, British Plant Growth Regulator Group, Bristol.

12. Hadavizadeh, A. and George, R.A.T. 1988. The effect of mother plant nutrition on seed vigour as determined by the seed leachate conductivity in pea (*Pisum sativum* L.) cultivar "Sprite". *Seed Science and Technology* 16: 589-199.

13. Hall, R.D. and Wiesner, L.E. 1990. Relationship between seed vigour tests and field performance of 'Regar' meadow bromegrass. *Crop Science* 30: 967-970.

14. Hampton, J.G. 1986. Effect of seed and seed lot 1000-seed weight on vegetative and reproductive yields of 'Grasslands Matua' tetraploid Italian ryegrass (*Lolium multiflorum*). *New Zealand Journal of Experimental Agriculture* 14: 13-18.

15. Hampton, J.G. 1990. Seed vigour. *Proceedings of an ISTA/USSR Seed Quality Symposium, Novosibirsk, USSR* (in press).

16. Hampton, J.G. and Bell, D.D. 1989. Seed quality and storage performance of prairie grass (*Bromus willdenowii* Kunth cv. Grasslands Matua). *New Zealand Journal of Agricultural Research* 32: 139-143.

17. Hampton, J.G. and Coolbear, P. 1990. Potential versus actual seed performance - can vigour testing provide an answer? *Seed Science and Technology* 18: 215-228.

18. Hampton, J.G., Charlton, J.F.L., Bell, D.D. and Scott, D.J. 1987. Temperature effects on the germination of herbage legumes in New Zealand. *Proceedings of the New Zealand Grassland Association* 48: 177-183.

19. Hampton, J.G. and Hill, M.J. 1990. Herbage seed lots: are germination data sufficient? *Proceedings of the New Zealand Grassland Association* 51: 59-64.

20. Kuo, W.H.J. 1989. Delayed-permeability of soybean seeds: characteristics and screening methodology. *Seed Science and Technology* 17: 131-142.

21. Matthews, S. and Powell, A.A. 1986. Environmental and physiological constraints on field performance of seeds. *HortScience* 21: 1125-1128.

22. Marshall, A.H. and Naylor, R.E.L. 1984. Reasons for poor establishment of direct reseeded grassland. *Annals of Applied Biology* 15: 87-96.

23. Miller, J.E. 1988. A project to identify causes of

seedling abnormality in white clover (*Trifolium repens* L.). Internal Report, Official Seed Testing Station, Ministry of Agriculture and Fisheries, Palmerston North, New Zealand.

24. Naylor, R.E.L. 1981. An evaluation of various germination indices for predicting differences in seed vigour in Italian ryegrass. *Seed Science and Technology* 9: 593-600.

25. Perry, D.A. 1981. Introduction. pp 3-7. In: Handbook of vigour test methods. ISTA, Zurich.

26. Powell, A.A. 1985. Impaired membrane integrity - a fundamental cause of seed quality differences in peas. In: The Pea Crop: a basis for improvement (ed. P.D. Hebblethwaite, T. Dawkins, M.C. Heath), pp 383-394, Butterworths, London, UK.

27. Powell, A.A. 1988. Seed vigour and field establishment. *Advances in Research and Technology of Seeds* 11: 29-61.

28. Scott, D.J. and Hampton, J.G. 1985. Aspects of seed quality. In: Producing Herbage Seeds. (ed. M.D. Hare, J.L. Brock), pp 43-52. Grasslands Research and Practice, No. 2, New Zealand Grassland Association.

29. Wang, Y.R. 1989. A study of the relationship between seed vigour and seed performance in *Trifolium pratense* L. cv. Grasslands Pawera. MAgrSc thesis, Massey University, Palmerston North.

30. Wang, Y.R. and Hampton, J.G. 1989. Red clover (*Trifolium pratense* L.) seed quality. *Proceedings of the Agronomy Society of New Zealand* 19: 37-42.

31. Wang, Y.R. and Hampton, J.G. 1991. Seed vigour and storage in Grasslands Pawera red clover. *Plant Varieties and Seeds* 4: 61-66.