Vigor and Seed Performance

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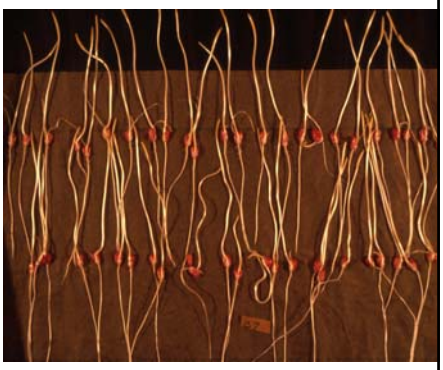
Seed vigor – introduction and history

- Seed vigor is a measure of the extent of damage that accumulates as viability declines
- Damage accumulates in seeds (rate primarily determined by moisture and temperature) until seed is unable to germinate and eventually dies.
- Vigor tests are designed to reveal subtle signs of damage, and provide a more reliable indicator of field/greenhouse performance than viability (germination) tests.



Seed vigor - history

- F. Nobbe (1876) reported on 'germination energy'; introduced the term 'triebkraft' meaning 'driving force' or 'shooting strength' in his Handbuch der Samendurde (Berlin).
- Idea of seed vigor advanced more rapidly after World War II; by 1950, the cold test for corn seed was in routine use by seed testing labs and hybrid seed companies for quality control.
- AOSA (Assoc. of Official Seed Analysts) efforts on a vigor testing handbook intensified in the 1970's; continues to present in cooperation with SCST (Soc. of Commercial Seed Technologists), others (e.g ISTA).
- corn cold test

Uses for seed vigor information

- Seed producers use vigor data to monitor seed quality during harvest, drying, conditioning, storage.
- Inventory management and seed carry-over decisions are aided by vigor test data; especially critical for international seed marketing.
- Breeding programs can employ vigor tests to develop cultivars with improved seed performance
- While many uses exist for seed vigor information, the underlying reason for vigor testing is to determine the true value of a seed lot.

Seed quality components

- Seed quality is a multifaceted concept comprising several components
- For many seed testing labs, between 80-90% of all tests requested are for purity and germination
- Other components of seed quality can be grouped into three categories:
  - **Description**: species and cultivar purity; analytical purity; uniformity; seed wt
  - **Hygiene**: noxious weed contamination; seed health; storage fungi contamination; insect and mite contamination
  - **Potential performance**: germination; vigor; moisture content; field emergence and uniformity; storability

(Coolbear and Hill, 1988; Hampton, 1994)

The concepts of seed viability and seed vigor

- Before proceeding with a definition of seed vigor, it is helpful to review the relationship of seed vigor to other components of physiological seed quality (viability and germination:
- This includes the relationship of physiological seed quality to seedling performance, and changes in seed quality that occur during seed development, maturation, and deterioration

- Germination capacity of a seed lot is expressed in terms of germination percentage as determined in a std. germination test.
- Germination test methods have been refined to a high level of reproducibility and reliability
- The lab germination % indicates those seedlings that developed the essential structures needed for the development of a normal seedling under favorable conditions.
- Seedlings that are classified as abnormal are assumed as unlikely to develop normal plants
- The germ test is performed under optimum conditions designed to determine the maximum germination potential of a seed lot.

Viability vs. vigor

- Germination test results can provide an accurate estimate of seedling emergence in the field or greenhouse, provided conditions at planting are close to optimum.
- However, in many situations the seedbed environmental conditions at planting are less than optimum and can impose moderate to severe stress on the seed, which can delay or prevent germination.
- These stress conditions can lead to seedling emergence that is far below the levels reported on the germ test.

Viability vs. vigor (cont.)

- High germinating seed lots of the same variety and production year may perform quite differently when planted under identical, but stressful, field or greenhouse conditions.
- Reason for this variable performance is that deterioration in seed lots can occur long before there is a detectable change in germination. This is a major limitation of the std. germination test

Seed vigor testing

- Another test, or series of tests, is needed to provide a more sensitive measure of physiological seed quality that more accurately reflects the potential performance of a seed lot if stress is encountered in the seedbed at planting
- The seed quality component responsible for performance differences among high germinating seed lots is referred to as **seed vigor**

Hypothetical example of germination and emergence of two seed lots.

Seed lot	% germ	----% Seedling emergence---- Near ideal conditions	Slightly unfavorable	Stressful conditions
A	90	88	80	70
B	90	87	60	40

(TeKrony and Spears, 2002)

Seed vigor – definitions

- Definition of seed vigor has been modified many times.
- The definition adopted by the Association of Seed Analysts (AOSA) states: 'Seed vigor comprises those seed properties that determine the potential for rapid, uniform emergence, and development of normal seedlings under a wide range of field conditions'.

- The International Seed Testing Association (ISTA) definition (June 2001) specifies some of the characteristics encompassed within the term vigor:
- Seed vigor is a sum of those properties that determine the activity and level of performance of seed lots of acceptable germination in a wide range of environments
  - Rate and uniformity of seed germination and seedling growth
  - Emergence ability of seeds under unfavorable environmental conditions
  - Performance after storage, particularly the retention of the ability to germinate
- A vigorous seedlot is one that is potentially able to perform well even under environmental conditions that are not optimal for the species.

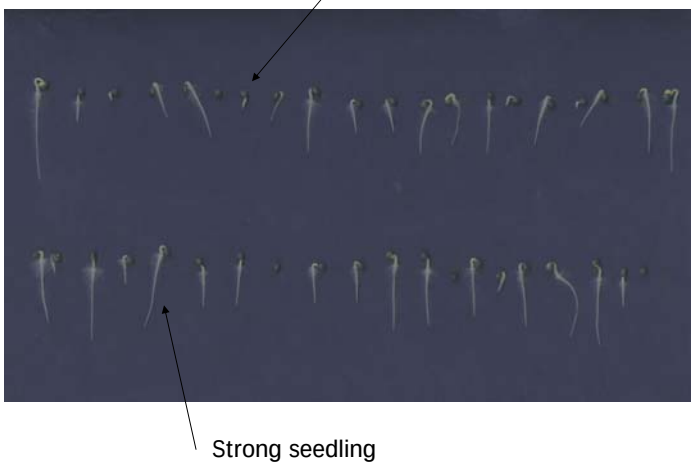
Seed vigor characteristics

Comparison of the characteristics of high and low vigor seed lots

	-----Vigor level-----	
	High	**Low**
Mean rate of germination	Fast	Slow
Synchrony of germination	Good	Poor
Mean seedling size	Large, uniform	Small, variable
Emergence potential	Good in most soil conditions	Poor in less than optimum soil conditions
Storage potential	Good	Poor

Encyclopedia of Seeds, pg. 742

Seed vigor imaging system

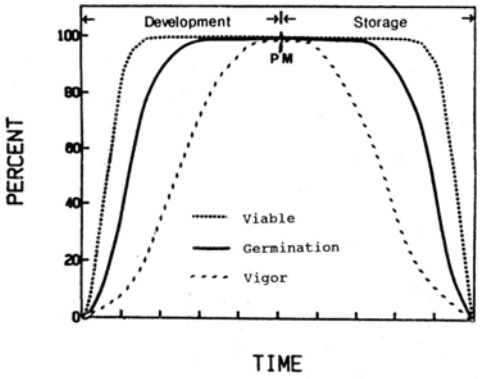


Devel. of seed viability, vigor

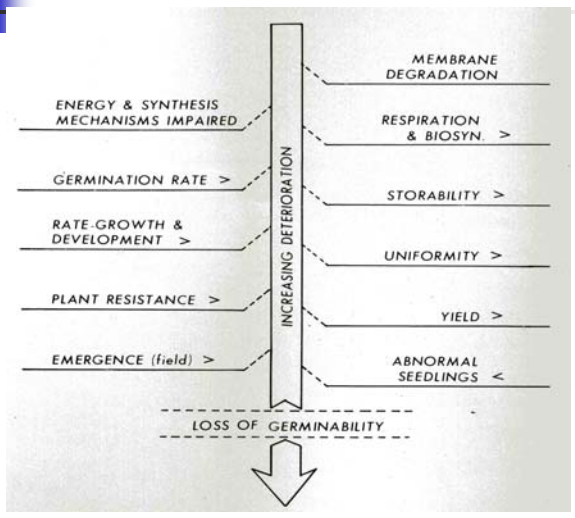
- The seed embryo is viable soon after fertilization, but does not reach its maximum germination potential until much later during maturation.
- Maximum seed vigor occurs even later and is closely associated with the accumulation of maximum dry wt of the seed, which is termed physiological maturity (PM).
- The maximum physiological quality for seed of most plants (except some fleshy-fruited species) occurs at PM.
- Seeds of most crops are high in seed moisture (30-60% fwb) at PM, which prevents commercial harvest.
- Seed deterioration begins immediately after PM while the seed is in storage on the plant and continues after harvest

Seed viability and vigor

- Deterioration may occur rapidly over a few days, or it may take several years to measure noticeable changes in seed quality.
- As deterioration occurs, physiological quality changes in inverse order of seed development, with seed vigor declining first followed by loss of germination and viability.



Changes in seed during deterioration



Delouche and Baskin, (1973)

Seed vigor tests

- Mechanisms of seed vigor are complex, and have implications for the practical determination of seed vigor.
- Vigor cannot be directly assayed (as germination) with results expressed in absolute terms.
- Seed scientists have searched for relatively simple laboratory tests that, in some way, are able to provide an indication of seed vigor.
- Vigor tests are available for many agronomic and horticultural crops; reliability and accuracy has been measured in comparison to field performance

Seed vigor tests (continued)

- Detailed descriptions of commonly used vigor tests have been published in the Seed Vigor Testing Handbooks developed by the seed vigor committees of the AOSA and ISTA.
- These tests are routinely used by the seed industry to evaluate “in house” seed vigor of many crops (maize, cotton, soybean, garden pea, sweet corn) during production, marketing and storage.
- A survey in N. Amer. reported that 85% of all private and public seed testing labs were conducting vigor tests and that 100% of all corn, cotton, sweet corn and garden pea seed was tested for vigor by major seed companies before marketing.

(Ferguson, 1990; 1995)

Seed vigor tests (continued)

- While seed vigor testing has been widely used by the seed industry for many years, it has been difficult to standardize.
- Strategy has been to measure some aspect of seed performance or condition that reflects the stage of seed deterioration.
- Goal: practical, reliable vigor test(s) that can be easily interpreted and standardized to provide an indication of field performance.
- Direct or indirect analytical procedures have been used to evaluate the vigor of seed lots of commercially acceptable germination under standardized conditions.
- Three major categories of vigor test methods:
  - Stress tests
  - Seedling growth and evaluation tests
  - Biochemical tests

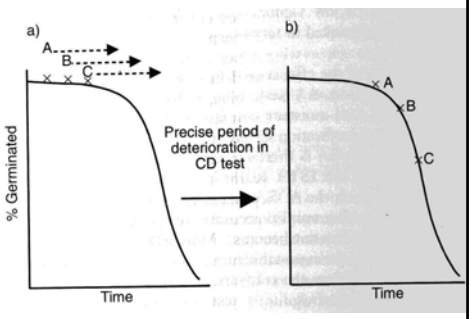
Seed vigor tests (continued)

- Tests listed in handbooks as 'recommended' for a species have been rigorously evaluated through recognized protocols including extensive referee testing and many comparisons to emergence performance.
- Tests listed as 'suggested' need additional referee testing and have not completed evaluation for each species.
- Commonly used vigor tests are the cold test for corn, conductivity for garden pea and accelerated aging for soybeans
- **Stress tests** include:
  - Accelerated aging (AA)
  - Cold test
  - Saturated cold test
  - Saturated salt AA (SSAA)
  - Cool test
  - Controlled deterioration

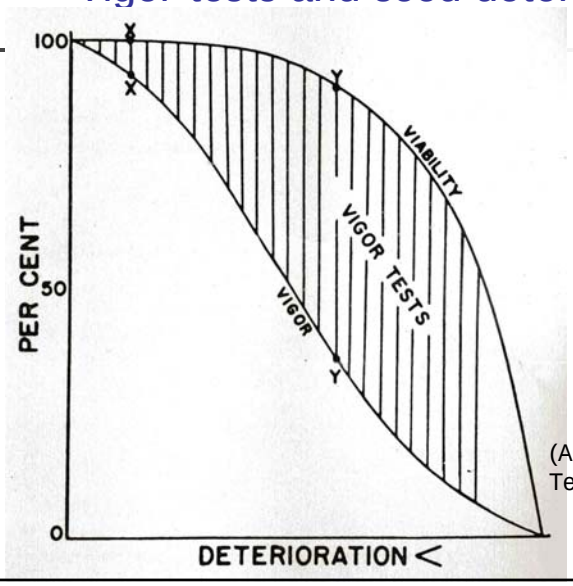
SSAA testing supplies

Seed vigor tests (continued)

- Example of stress test concept w/ controlled deterioration (CD)
- **Seedling growth** and **evaluation tests** include:
  - 1st count of standard germ test
  - Seedling growth rate (e.g. SVIS, other)
  - Seedling weight tests
- **Biochemical** vigor tests:
  - Conductivity
  - Tetrazolium



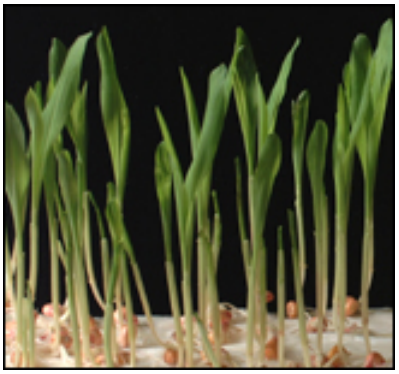
Vigor tests and seed deterioration



(AOSA Seed Vigor Testing Handbook)

Factors affecting seed vigor

- To achieve maximal seed vigor of a given cultivar in seed production, efforts must focus on:
  - Producing a seed crop in the best possible environment for development of vigorous seeds
  - Harvesting as soon as possible after physiological maturity (PM)
  - Handling, conditioning, and storing seed to minimize damage, slow deterioration



Seed vigor is inherently variable

Year	Standard Germination	Cold Test	Accelerated Aging	Total Weight	Vigor Index*
	%			mg/seedling	
1982	88	68	-	47	5.3
	94	64	-	61	6.3
	94	94	-	83	9.7
	96	94	-	81	10.0
1983	89	48	73	62	5.2
	88	86	90	53	7.5
	98	90	92	74	9.2
	97	98	96	83	10.0
1984	93	45	82	39	4.5
	88	57	81	48	5.5
	94	97	96	71	9.2
	98	97	99	78	9.7

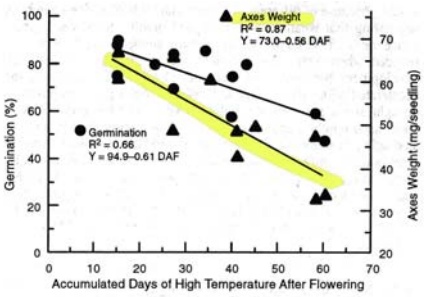
(TeKrony, Egli, and Wickham, 1989)

Seed vigor and forage grass performance

- While vigor tests are better indicators of field performance than std. germ results, they cannot account for all variability seen in field emergence or subsequent yield results, etc. (Hall and Wiesner, 1990)

Seed Lot	Standard Germination	Accelerated Aging	Forage Yield	Total Seedling Emergence
	%	%	kg ha^{-1}	plants m^{-1}
863	94 cd*	76 e	5580 d	35 ab
867	86 c	43 bc	5240 cd	33 ab
865	90 cd	35 b	4150 ab	38 ab
862	94 cd	58 d	3930 ab	35 ab
869	60 b	15 a	3840 ab	28 a
8610	49 a	13 a	3350 a	34 ab

Soybean germination and seedling vigor for seeds maturing in high temp (32/28ºC) stress



(Keigley and Mullen, 1986)

Agronomic practices during seed production affect vigor

- Tillage practices
- Plant population
- Planting date
- Soil tilth
- Harvest
- Soil fertility
- Weed, insect, disease management
- Irrigation
- Others...

Fertilizer rates and perennial ryegrass seed vigor (Rowarth et al., 1999)

N application strategy[1]	TSW g	Seed N concentration (%)	Seed N content (g/1000 seeds)	Germination (%)	
				Pre-AA	Post-AA
0-0-0	2.26	1.24	0.028	98	49
0-50-150	2.30	1.35	0.031	99	55
50-50-150	2.35	1.49	0.035	98	79
50-100-150	2.44	1.48	0.036	98	76
50-100-200	2.43	1.52	0.037	98	86
LSD P<0.05	0.10	0.05	0.004	ns	9.9

[1] N rates (kg/ha N) in autumn, winter and early spring.

Planting date and pea (Pisum sativum L.) seed quality

Table 4. Effect of time of sowing on seed quality of hand harvested garden pea (adapted from Hampton, 2000).

Time of sowing[1]	Harvest date	Germination (%)	Conductivity (µ/cm/g)	Hollow heart (%)
Year 1				
Nov 15	Jan 27	90a	15.28b	11.8b
Dec 15	Feb 24	96a	11.86a	2.8a
Year 2				
Nov 15	Jan 24	92a	13.25b	12.2b
Dec 15	Feb 20	93a	7.94a	6.3a

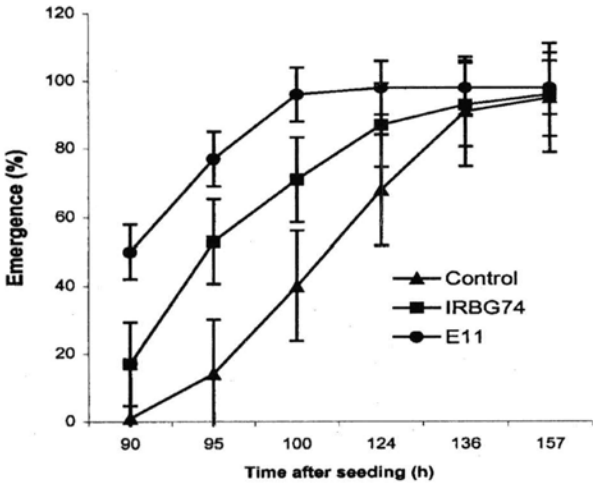
[1] In the same field

Seed vigor and crop yields

- Seed vigor effects often more dramatic on vegetative (e.g. forages, greens) and early reproductive crop yields (e.g. tomato, garden beans and peas) vs. full reproductive crop yields (soybean, small grains, dry beans, corn).
- High vigor planting seed for all crops is justified to ensure adequate plant populations across wide range of field conditions that occur during emergence.

(TeKrony and Egli, 1991)

Seed inoculation of rice seed w/ rhizobial strains can improve 'vigor'



(Biswas et al., 2000; Agron J. 92:880-886)

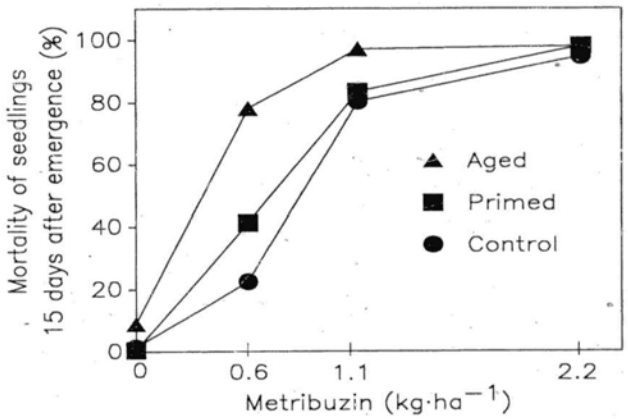
Seed insecticide trts. best when appl. to high vigor sw. corn seed

Variety	Seed treatment	% germination				
		Non-aged seeds			Aged seeds	
		4-day	Final (7-day)	Cold test	4-day	Final (7-day)
Sprint	Non-treated	92abc	98ab	87ab	33c	85ab
	Treated[b]	71d	90c	80b	6d	77b
Dynamo	Non-treated	86bcd	98abc	84b	60b	94a
	Treated[b]	82cd	94ab	80b	33c	78b
Bonus	Non-treated	100a	100a	94a	93a	96a
	Treated[b]	96ab	97abc	95a	92a	94a

[a] Numbers within columns followed by the same letter are not significantly different according to Tukey's HSD at the 0.05 level of significance.
[b] Imidacloprid (Gaucho® 600FS) was applied with a Hege II seed treater at 2.5 a.i./kg seed.

(Kuhar et al., 2002.)

Initial seed vigor is related to herbicide injury and tomato seedling survival



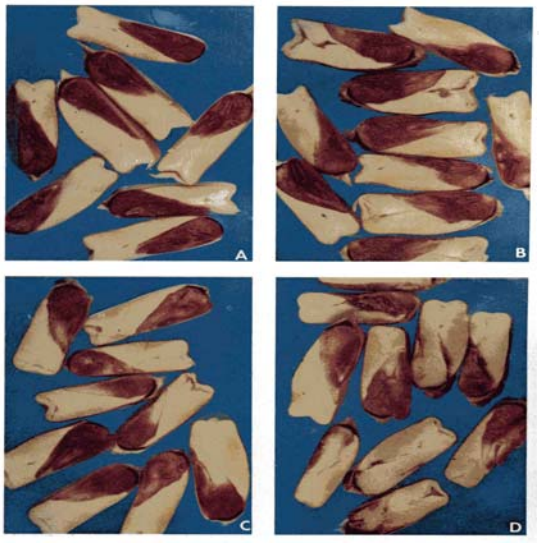
(Argerich et al., 1990)

Basic requirements of a vigor test

- Objective, rapid, simple and economically practical
- Reproducible and interpretable
- Provide a more sensitive index of seed quality than the germination test
- Provide a consistent ranking of seed lots in terms of potential performance

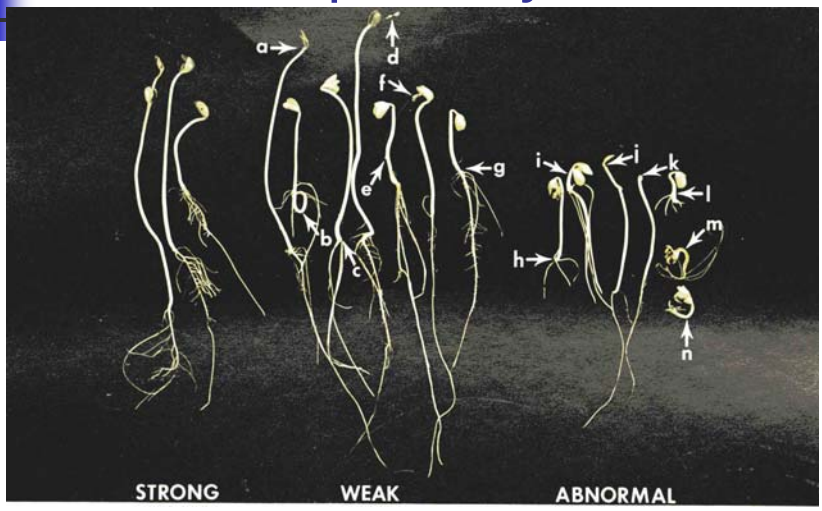
(McDonald, 1980; Perry, 1984)

Visual assessment of corn seed vigor with TZ test

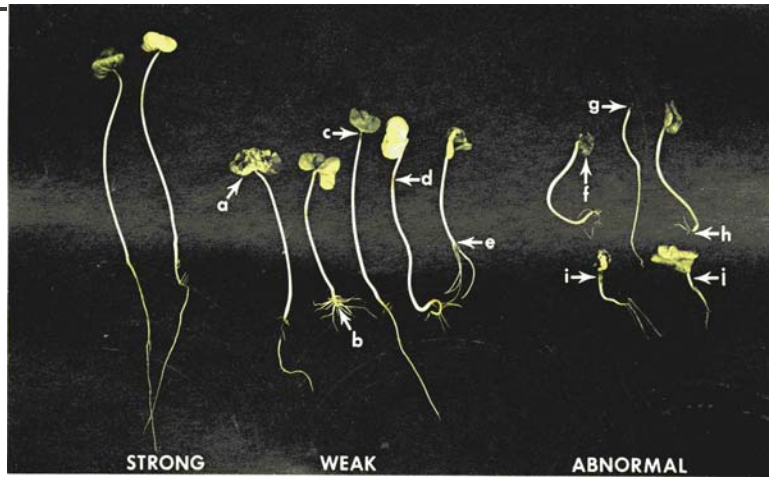


(Seed Vigor Testing Handbook)

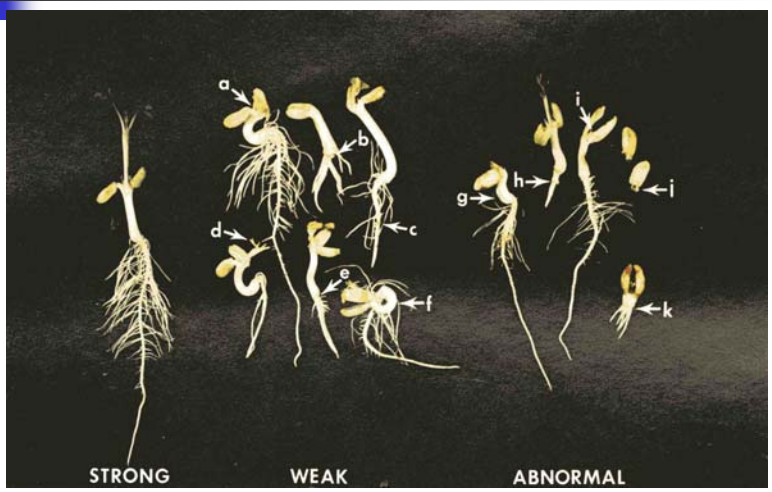
Seedling vigor classification example - soybean



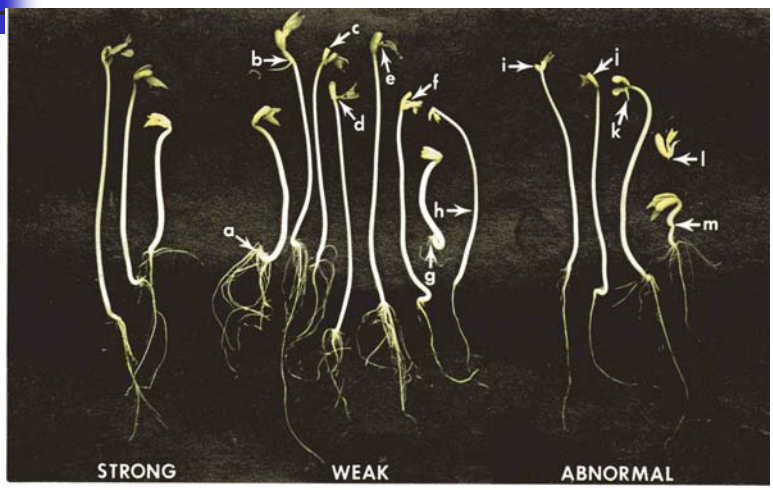
Seedling vigor classification example - cotton



Seedling vigor classification example - peanut



Seedling vigor classification example – garden bean



Precision is an essential aspect of vigor testing

Why is precision important?

- Changes in seed vigor may occur very rapidly
- Minor differences in the testing environment (e.g. temperature, initial seed moisture, test duration) can cause major changes in test results
- Improper equipment and supplies will influence result

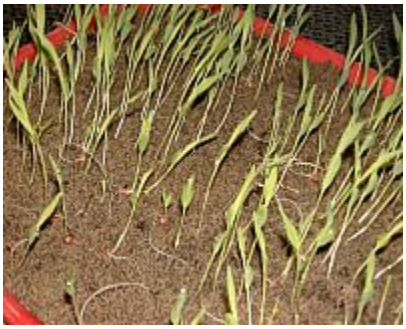
How to achieve precision within and among seed testing laboratories

- Use of control samples for all vigor tests and species tested
- Seed storage and maintenance
- Seed moisture measurement and adjustment (as needed)

(TeKrony and Spears, 2001)

Interpretation of seed vigor test results

- Seed vigor testing programs cannot be established in seed laboratories overnight. Expertise of analysts is acquired over time.
- Precision in vigor testing methodology and equipment is more critical than in germination testing, because the laboratory is attempting to measure minor changes in seed deterioration that are not obvious in germination test.
- The expectation that an analyst can infrequently analyse an isolated sample to establish whether it has an acceptable level of vigor is unrealistic.



Limitations of seed vigor tests

- Precision and standardization of seed vigor (SV) testing methods can only be determined by referee testing among seed labs.
- SV tests do not predict percentage field emergence, but neither does standard germ. However, SV tests do relate better to field emergence under stressful soil conditions than does standard germ.
- Values obtained from SV tests are relative, not absolute values of vigor
- Comparison of the results of different vigor tests is sometimes difficult because results are often expressed in different units.
- Interpretation of results requires lab analyst experience, and education for the seed industry and consumer.
- Cut-off points between acceptable and unacceptable levels of vigor have only been established for a few recommended tests (e.g. conductivity test for pea) and must be established for other frequently used vigor tests.

(TeKrony and Spears, 2001)

Usefulness of seed vigor tests

- SV tests rank seed lots for physiological quality, providing an indication of seed deterioration before this is noticeable in germination test results.
- SV tests identify seed lots that, in spite of acceptable germ test results, are unlikely to store well or perform well in suboptimal conditions.
- SV test results provide information which can be used to plan inventory carryover and marketing strategies.
- SV tests provide information which can be used by the seed industry to answer customer inquiries about seed lot performance or to prevent litigation
- SV tests are a great tool for in-house quality control. Seed companies routinely use vigor tests to make quality assurance decisions during production, conditioning, storage and marketing.

(TeKrony and Spears, 2001)

"There is an immense need for more vigor testing research"

(M. O'Neill, R.S.T.; ISST Rpts, 2003)

Additional readings and references

- Seed Vigor Testing Handbook (AOSA/SCST) 2002. 105 p.
- Seed Quality: Basic Mechanisms and Agricultural Implications. 1995. A.S. Basra (ed.); Food Products Press; Binghampton, NY; 389 p.
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