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SEED VIGOR AND VIGOR TESTS[1/]

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The fundamental objective of seed testing is to establish the quality level of seed. There are, of course, other objectives, e.g., check labeling claims, but primarily seed testing provides a basis for consumer discrimination among seed lots. Within recent years certain phases of seed testing have come under increasing attack by seedsmen, agricultural research workers and some analysts as being inadequate and/or unrealistic. This is particularly true with respect to the standard germination test. Criticism of the germination test is usually based on the fact that the test is made under highly favorable, artificial conditions. Critics contend that such tests do not adequately evaluate the stand-producing potential of seed. They suggest that the additional factor of seed vigor needs to be considered.

In some respects, the trend in seed testing is almost opposite that indicated from a consideration of vigor. Refinements of germination methods are basically concerned with obtaining maximum germination; the more favorable the germination conditions the greater is the contribution of weak, nonvigorous seeds to the germination percentage on the seed tag. Similarly, the long test periods specified in the Rules for Testing Seed (2)[2/] permit development of weak seedlings to the extent that they are classed as normal seedlings on the final count. It might be argued that long test periods are necessary for accurate evaluation of dormant seeds. This argument is valid. However, elementary consideration of the situation reveals that test periods for non-dormant seed are also prolonged and that germination periods remain the same length whether seeds are in a dormant condition or not. There is also some question that seeds which are still dormant at planting time make any significant contribution to stand establishment or in stand replacement. In one sense, the final result of a delay in germination and emergence is the same, whether caused by low vigor or dormancy.

Recent papers by Isely (12, 13)[2/] and Steinbauer (21) have pointed out the importance of vigor and the necessity for analysts to take this concept into consideration in charting future objectives for seed research.

Concept of Vigor

In a negative sense, seed vigor is generally thought of as "something" not adequately measured or reflected by the standard germination test. On the positive side no such precision of definition is possible. In trying to arrive at a concept of vigor it is perhaps best to proceed by approximations, i.e., to consider several views and hope that some clarification will result from a discussion of their weak and strong points.

Isely (12) pointed out that two views predominate in most concepts of vigor: (1) susceptibility to unfavorable field conditions; (2) vigor *per se* as reflected in speed of germination and rapidity of growth rate of seedlings. He further stated that these may be regarded as separate entities or as facets of a single physiological complex.

The view that vigor (or lack of vigor) is usually manifested as susceptibility to unfavorable field conditions shifts the emphasis from the seed to the environment. It follows from this concept that vigor is a significant factor only under unfavorable field conditions. Differences in seed responses under favorable conditions are ignored. Another implication of this concept is that the only fate of seeds low in vigor is death in the seed or young seedling stage and that vigor differences are of no importance or non-existent beyond these stages. Indeed, the literature contains very little data—none of which is very conclusive—showing that vigor differences in growing plants affect yields. However, in modern agricultural operations yield, although still the basic consideration, is

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1/ Journal Paper No. 883 of the Mississippi Agricultural Experiment Station.

2/ Refers to literature cited.

not the only important factor. Rapidity and uniformity of emergence are becoming prime considerations along with percentage emergence or stand. This is particularly true in crops where the application of herbicides is timed to stage of plant development. Uniformity of maturity is another important consideration. A plant low in vigor that matures late contributes little to yield and may actually detract from the quality of the crop as a whole.

Another aspect of the concept of vigor discussed above should perhaps be mentioned. Undue emphasis appears to be placed on the role of microorganisms in germination failure of low-vigor seeds. The fact that various microorganisms are found associated with ungerminated seed in soil should not necessarily lead to the conclusion that these microorganisms are the basic cause of germination failures. There is some evidence that microorganisms play a secondary role in seed and seedling mortality. A seed or seedling inherently weak in vigor is more susceptible to a variety of adverse conditions including microbial attack than a highly vigorous one.

Although the concept of seed vigor as susceptibility to unfavorable field conditions has rather serious limitations, it nevertheless, has great appeal. The recognition of the importance of the environment in stand establishment is significant. Certainly differences in vigor are most obvious under unfavorable field conditions.

The second view that vigor is manifested by rapidity and "strength" of germination and growth rate of seedlings is also somewhat inadequate. This view does not sufficiently cover an important area of seed quality, viz., mechanical damage. This is particularly true when the concept is applied to seeds with recently sustained mechanical injuries. Also, application of this concept to seeds with short-term, post harvest dormancy can lead to very erroneous conclusions.

On the positive side the vigor per se concept does place the emphasis on the seed where it belongs. It also appears to be the more fundamental concept. It is a direct expression of the physiological and to some extent the physical condition of seeds. The concept is also sufficiently broad to encompass vigor differences beyond the seed and seedling stage. Moreover, it has application not only under unfavorable conditions but applies equally well under favorable conditions.

It is relatively easy to discuss what vigor is not, but much more difficult to elaborate a concept of sufficient scope to precisely define it. Isely (13) in summary defined vigor "as the sum total of all seed attributes which favor stand establishment under unfavorable conditions." Revision of this definition does provide a practical concept: vigor is the sum of all seed attributes which favor rapid and uniform stand establishment in the field. It should be pointed out, however, that this definition is a limiting one, i.e., it does not extend beyond stand establishment.

In developing a vigor test it is essential that the relation between vigor and viability (standard germination) be clearly understood. An understanding of this relationship is in itself a concept of vigor. Diagrammatic representations of the relation between vigor and viability have been presented by Isely (12) and Steinbauer (21). The scheme presented in Figure 1 is adapted from Steinbauer. The viability curve was drawn from unlished data on ryegrass storage under warehouse conditions over a five-year period. The vigor curve is hypothetical but based upon several observations, viz., that initially loss in vigor tends to parallel loss in viability, then vigor declines very rapidly, and finally rate of loss slows as zero vigor or death of all seeds is approached. The importance of vigor is indicated by consideration of points X and Y on the vigor and viability curves. The difference between X and Y on the viability curve is not very great. However, corresponding vigor differences at these points are quite pronounced. The slightly lower viability at point Y is very revealing if other points on the curve are also known. Unfortunately, analysts know relatively little about the history of most lots of seed they test. On the other hand, the relatively low vigor level at point Y has considerable significance independent of other points on either curve.

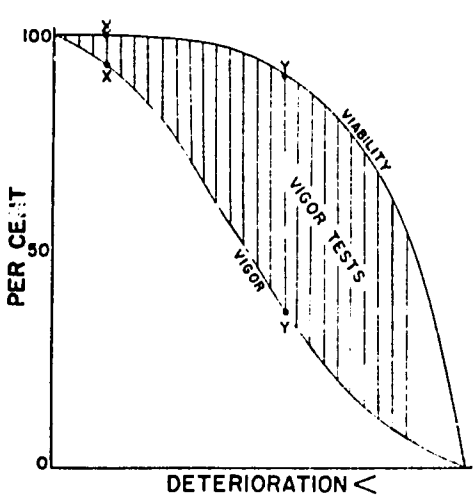

Fig. 1—Relationship of seed viability and vigor during seed deterioration.

Vigor Tests

Methods of vigor testing have become so intimately associated with the various concepts of vigor that it is quite difficult to discuss them separately. For example, the concept that vigor is manifested as susceptibility to unfavorable field conditions appears to have naturally evolved from the cold test for corn. Not only was the concept derived from the test, but the unique success of this vigor test has added considerable weight to the concept.

Isely (12) has categorized vigor tests into two types: (1) direct tests which simulate pertinent unfavorable field conditions on a laboratory scale and (2) indirect tests which measure measure certain physiological attributes of seeds. Most of the emphasis on vigor tests in this country has been focused on tests of the direct type. The principal advantage advanced for this type of test is that it simultaneously evaluates all vigor factors. Another advantage is psychological—that methods of the test bear some resemblance to the stresses which seeds encounter in the field. The disadvantages and difficulties of direct tests are considerable and probably account for the relatively slow progress on vigor testing in general. The variability inherent in direct test methods leads to inconsistency in tests results both within a laboratory and between laboratories. Attempts to standardize tests of this type have not been successful. Another disadvantage of the direct type test is that if pertinent field conditions are to be simulated, several distinct methods might have to be employed for the same crop to cover the entire area of production. In one area drought might be the prevailing adverse factor at planting time while in another area cold, wet conditions might be of prime importance.

Indirect type tests have the advantage that the variables can be precisely controlled allowing reproducibility of results. They are usually less time consuming, less complex, and require less equipment than direct type tests. They also allow direct vigor comparisons over a wide geographic area. The primary disadvantage of the indirect type tests which has been advanced is that such tests do not simultaneously evaluate all vigor factors, particularly injuries and morphological abnormalities. This objection is only partially valid as most morphological abnormalities are detected in the standard germination test. Mechanical and other injuries after normal periods of storage are reflected in a general physiological deterioration in seeds. For example, Rice (20) has shown that mechanical injuries to corn seed are reflected after normal storage periods in a slower growth rate of the roots.

Several methods of the indirect and direct type have been developed or proposed. As previously mentioned, the cold test for corn—a direct test—is the only vigor test in widespread use today. Literature pertaining to the development and use of this test have been adequately reviewed (6, 11, 23). Clark (7) has adapted cold test procedures for a vigor test of peas. Other adaptations of the cold test technique have also been used by several commercial seed firms for vigor determination of other field and vegetable seed. These various type cold tests correlate well with field emergence particularly when the crops are planted during the early part of the season. They are, however, highly variable and not always reproducible.

Within recent years considerable research has been directed toward development of vigor tests of the indirect type. Much of the work has been exploratory. With the exception of rate of germination tests, none of the indirect tests are in widespread use in this country. In Europe, several tests of the indirect type have been in use for many years (8, 9, 14).

Indirect tests can be classified into four general groups:

1. Biochemical tests. Use of the tetrazolium test as a means of evaluating vigor has received considerable attention within recent years. Moore (17, 18) has stated that careful examination of tetrazolium staining patterns reveal seed weaknesses not detectable in the standard germination test and that both mechanical injuries and physiological aging are detectable. Rice (20) found that the intensity of stain or color developed within a specified time compared favorably with other vigor tests for corn.

2. Growth rate tests. Speed of germination or "first count" tests (5, 8), growth rate of seedlings (9), and related tests such as dry weight of seedlings (10) have been used to evaluate vigor.

3. Stress tests. Reaction of seeds to conditions of stress as a means of evaluating vigor has been explored by several investigators. Stress conditions which have been used are unfavorable temperature and moisture levels (4, 24), exposure under vacuum (17),

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seed soaks in sodium hydroxide and hot water (3), and mechanical barriers such as brick gravel (14).

4. Physical measurement tests. Recently Presley (19) reported on a vigor test for cotton based on permeability changes associated with deterioration. He measured the rate of leaching of electrolytes from seeds by means of a resistance bridge and found good correlation between extent of leaching and field performance. Vaughan (22), McGinnis (16), and Kneeborn (15) have found a correlation of seed size with vigor.

The great potential of tests of the indirect type is that they offer the possibility of development of vigor tests that not only measure vigor as well as any other type test but are also simple and which are reproducible within laboratories as well as between laboratories.

It might be pertinent here to consider several recent studies on indirect methods of measuring vigor.

Caldwell (4) developed a vigor test for peas based upon stress conditions of high moisture and high temperature. This test, conducted at 30°C. in sterile sand at a moisture level of 70 percent of saturation, more clearly detected differences in vigor between pea seed lots than did the standard germination test or several other type vigor tests (Table 1).

Table 1. Germination percentages of four lots of pea seeds obtained under laboratory conditions and in the field.[a]

Lot	Field Emergence	Sterile Sand 30° C.[b]	Standard Laboratory Test[c]
1	87.13	92.00	91.50
2	85.88	93.50	95.00
3	59.71	70.50	89.00
4	46.04	29.50	83.50
Mean	69.69	71.37	89.88

[a] Adapted from Caldwell (4) p. 33.

[b] Sand at 70% of saturation

[c] Standard laboratory tests were made in sand benches at approximately 20° C.

Barnes (3) compared germination of sorghum lots (Table 2) under several germinative conditions. Seeds were given pre-planting treatments of two-minute soaks in five percent NaOH and five-sec. soaks in 100°C. water. In addition, a four-day count and a final count was made under standard germination conditions and percentage emergence under unfavorable field conditions was determined as a basis for evaluating the other tests. Tests conducted under all the above conditions were capable of detecting differences in vigor between seed lots, however, the test utilizing NaOH pretreatment appeared to give slightly higher precision in vigor measurement.

Rice (20) studied the evaluation of vigor in corn with tetrazolium as compared with other methods (Table 3). Employing INT tetrazolium he found that stain intensity obtained in 15 min. provided as precise a measure of vigor as the cold test. Rate of root growth also proved very effective in detecting vigor differences.

Selection of the above data for illustrating various approaches to indirect vigor testing methods was based upon the authors' familiarity with the work. These studies were largely of an exploratory nature and the intention here is not to present them as finished vigor tests but only to illustrate the potential of indirect type tests.

The exact methods, whether of the direct or indirect type, of evaluating vigor are of small consequence as long as good differentiation of vigor differences between seed lots is obtained. From a practical standpoint, however, the test used should be reproducible and be fairly simple to conduct.

Table 2. Comparative germination percentages of 14 lots of sorghum seed in laboratory and field tests.[a]

Lot	Field Emergence	5% NaOH (2 min.)	100°C. H_2O (5 sec.)	4-Day Count	Final Count
1	4.0	12.0	5.0	6.0	12.0
2	26.0	34.0	28.0	43.0	48.0
3	32.0	46.0	22.0	49.0	59.0
4	42.0	57.0	62.0	64.0	68.0
5	52.0	54.0	28.0	81.0	83.0
6	57.0	95.0	76.0	43.0	96.0
7	58.0	63.0	68.0	82.0	85.0
8	59.0	81.0	88.0	57.0	88.0
9	66.0	57.0	37.0	75.0	84.0
10	70.0	85.0	83.0	82.0	96.0
11	72.0	83.0	61.0	80.0	88.0
12	72.0	85.0	23.0	91.0	92.0
13	74.0	85.0	59.0	95.0	96.0
14	79.0	99.0	96.0	99.0	99.0
Avg.	54.5	66.9	52.6	67.6	78.5

[a] Adapted from Barnes (3) p. 24.

Vigor and Research in Seed Technology

The importance of vigor as a factor in seed quality is clearly indicated by trends in recent seed storage research. In the past, the results of storage research were evaluated primarily in terms of germination percentage or viability. Now, however, all well planned

Table 3. Comparison of INT vigor ratings on corn with cold test results and root growth.[a]

Lot No.	INT Tetrazolium	Cold Test	Standard Test	
	Color Intensity 15 Minutes	Germ. %	Root Growth (mm.)	Germ. %
12	Dark Red	86	154.0	97.0
10	Dark Red	95	139.0	98.0
11	Red	80	150.0	90.0
9	Red	76	126.5	97.5
8	Light Red	86	117.5	98.0
6	Light Red	83	110.0	97.5
7	Pink	42	84.0	98.5
4	Pink	62	81.0	99.0
2	Pink	34	93.5	98.0
3	Light Pink	15	55.0	87.0
1	Light Pink	33	46.0	96.0
5	Very Light Pink	8	25.5	88.5

[a] Adapted from Rice (20) p. 22.

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storage work (1, 5) incorporates some type of vigor test as an integral part of the plan. Storage work which does not consider vigor tells only half the story. From an even broader standpoint all research in seed technology which is finally evaluated in terms of seed viability should also be evaluated in terms of seed vigor. Work on mechanical, chemical, thermal and insect damage to seeds as well as maturity studies would fall into this category. The inclusion of vigor as well as viability measurements in such research insures that full significance of the work will be realized.

The incorporation of vigor measurements in seed research as indicated above requires the development of suitable vigor tests for a wide variety of crops. Considerable research is in progress toward the development of methods for testing vigor of seeds, however, this area is still a relatively unexplored one and can effectively utilize the efforts of many more researchers.

It appears inevitable that vigor testing will occupy a prominent place in seed testing in the future. In this instance, however, the future is not a nebulous point in time. It is fast approaching. If seed analysts are to continue to provide the leadership in seed quality evaluation, they must not only recognize the importance of seed vigor but also must provide the framework within which this new concept can be put to practical use.

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