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CONCEPT AND IMPORTANCE OF SEED VIGOR

James C. Delouche 1/

Brief History

In 1980, the Association of Official Seed Analysts (AOSA) adopted the following definition of seed vigor:

"Seed vigor comprises those seed properties which determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions."

A few years earlier (1977), the International Seed Testing Association (ISTA) defined seed vigor as, (in part), "the sum of those properties which determine the potential level of activity and performance of the seed or seed lot during germination and seedling emergence." The very recent advent of formal definitions of seed vigor might suggest that seed vigor is a new idea or concept being positioned for exploitation, but this is not the case. The idea of seed vigor is not new. It developed in Europe in the early 1900s at the time seed testing was getting underway.

Very early in the history of seed testing, analysts noted differences in the capacity of seed within and among samples for rapid germination and seedling development and emergence through a physical barrier, i.e., the Hiltner brick-grit test first described in 1911. This capacity was called Triebkraft, meaning "driving force" or "shooting power." Later, the term "germination energy" gained ascendancy, especially in connection with rate of germination and seedling growth. By 1915, the germination energy determination - essentially a first count test - and the brick-grit test (cereal seed) were being routinely made in some European seed laboratories. During the same period and extending through the 1930s, there was much emphasis in the U.S. on use of soil tests to aid in interpretation of germination tests and to "calibrate" test results.

These developments are ample evidence that during the early years of seed testing - more than 50 years ago - analysts and seed botanists

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were not wholly satisfied with the germination test for evaluation of
the field or planting value of seed. They felt there was need for a
supplemental test(s) - such as the germination energy determination - to
evaluate properties of seed important in terms of emergence and
stand establishment which were not adequately assayed in the germination
test.

During the 1930s as the idea of germination energy reached its
zenith, work was beginning in the U.S. and Germany which was to have
profound effects on concepts of seed quality in general, and seed vigor
in particular. In the U.S. Reddy (Iowa State) and others developed the
cold test for corn seed, while in Germany Lakon developed the tetra­
zolium test. The earlier idea of germination energy and its application
in seed testing, the information obtained on seed and environment
interactions from studies of the cold test, and the insights into the
"dying of seed" gained through use of the tetrazolium test provided the
bases for the development of the present concept(s) and definition(s) of
seed vigor.

Isely (Iowa State, 1957) was perhaps the first to attempt a rigorous
conceptualization of seed vigor. Accepting one premise of the germi­
nation energy school, viz., vigor is a quality of germinable seed, he
then dismissed the central premise that vigor per se in terms of rate of
germination and seedling development is the, "key to .... success in the
field," and considered seed vigor as those, "seed attributes which favor
stand establishment under unfavorable conditions." In Isely's graphical
representation of vigor (Figure 1), a germinable seed is scaled for
vigor from low to high. The higher a germinable seed is on the vigor
scale, the greater is, "its chance for success under unfavorable condi­
tions." Delouche and Caldwell (Miss. State, 1960) believed that Isely's
concept wrongly implied that "vigor is a significant factor only under
unfavorable conditions," and that vigor per se is unimportant, and
proposed a modification of Isely's concept or definition: "vigor is
the sum total of all seed attributes which favor rapid and uniform stand
establishment." This modification took into account the rate of germi­
nation and seedling development or vigor per se idea, and extended the
influence of vigor to the whole range of field conditions which can
occur during the germination, emergence, and stand establishment period.
In their graphical representation of vigor (Figure 2), Delouche and
Caldwell advanced the idea that loss of both vigor and germinability are
consequences of deteriorative processes in seed, but a significant loss
of vigor usually occurs before germinability is affected.

Woodstock's (USDA, 1969) concept of vigor represents a synthesis of
the vigor per se and tolerance to environmental conditions ideas (Figure
3). It established two dimensions for seed vigor: an "intensity of
Greater vigor:

Seedling capable of emergence and continued growth under favorable conditions; the higher the seedling on the vigor scale, the greater its chance of success under unfavorable conditions.

Less vigor:

Seedling capable of emergence, but incapable of continued growth; abnormal sprouts of seed analysis tests.

Seed not dead in all its parts, but incapable of emergence.

Seed completely dead.

Normal sprouts of germination tests.

"Vigor" tests applicable in this area.

Dead seeds of seed analysis tests.

Figure 1. Schematic representation of the relationship between germination and vigor. From Isely (1958).
Figure 2. Relationships among seed vigor, viability (germinability) and deterioration, and the area for application of vigor tests. The X and Y points on the viability and vigor curves illustrate the increasing "gap" between germinability and vigor with increasing deterioration. From Delouche and Caldwell (1960).
Figure 3. Relationships among the rate (intensity of response/activity) and tolerance (to environmental stresses) dimensions of seed potential and "vigor", their product. Adapted from Woodstock (1969).
response" dimension which is manifested in rate of germination and seedling development, and an "environmental range" dimension which relates to the tolerance of seed to the diverse conditions of the seed bed. Although the two dimensions can be separately evaluated, in most cases they are just different manifestations of the over-all physiological "well being" of the seed. The rate of germination of a seed and its tolerance to environmental stresses both decrease as "vigor" decreases or deterioration progresses. The two dimensions of vigor integrated in Woodstock's concept are the most important in establishing a crop stand. And, they constitute the essential elements in the very practical AOSA definition of seed vigor.

The adoption of the AOSA definition of seed vigor and the "Vigor Testing Handbook" scheduled for publication in 1983 should clear most of the confusion and controversy which has attended vigor testing since the late 1950s. It is hoped the definition and handbook will also advance the use of the vigor tests in in-house quality assurance programs and stimulate the development of even better tests for measuring, as Woodstock put it, "the ability of seeds to germinate and produce useful growing plants under a range of field conditions which can be reasonably expected for the geographic location and kind of crop in question."

Importance and Uses of Vigor Tests

The germination test provides - and should continue to provide - the baseline information on the plant producing capacity of seed lots. It establishes the maximum capacity of lots to produce normal seedlings under very favorable field conditions. Vigor tests provide supplemental information on the capabilities of the germinable seed in a seed lot to produce normal seedlings under field conditions that are less than favorable, to germinate and emerge rapidly and uniformly, and to maintain their germinative capacity in storage. The supplemental information provided by vigor tests on the physiological status of seed is of great importance in quality assurance and control programs, consumer service activities, and research and development work.

Quality Assurance and Control

The physiological and physical qualities of seed can be damaged by drought stress during the development and maturation period, "weathering" prior to harvest, mechanical abuse during harvesting and handling operations, delayed and/or improper aeration and drying, unfavorable storage conditions, and during prolonged storage even under relatively favorable conditions. Severe "damage" reduces the percentage of germinable seed and can be detected by a germination test. A germination
test made, interpreted, and reported in the "standard" manner does not, however, provide much information on the extent to which the seeds still capable of germination have been damaged. It does not establish the level of vigor/deterioration of the germinable seed, which determines how well germination will be maintained until the seed are marketed, and how well the seed will perform when planted.

In a quality assurance and control program, it is important to know the germinative capacity and performance potential (i.e., vigor) of seed lots after each major operational stage so the rising investment in the seed can be stopped any time its quality falls below established or acceptable standards, and to identify operational procedures - or deficiencies therein - which are damaging to quality. It is equally or even more important in a quality assurance and control program to obtain information from which projections can be made about the quality of the seed in the future - the next marketing, distribution and planting season. A combination of the germination test, vigor tests and other special tests such as mechanical damage and seed health analyses can provide the information needed to monitor and control seed quality during the operational stages from production to storage, and to assure that lots of seed marketed are in good physiological condition.

Consumer Services

The more information a seedsman has on the quality of the seed lots in his inventory, the better he can serve his customers. Some seed lots of low or uncertain quality can be diverted to alternative markets, i.e., feed or grain, thus, reducing complaints (and claims). Lots marginal in quality can either be diverted to alternative markets, blended with high quality lots, or marketed at times and in areas where the probability of adverse conditions at planting time is minimal.

Some farmers are insisting on greater assurance about the plant producing potential of seed than the germination percentage printed on the seed label. Vigor test results can be used during the sales "negotiation" to demonstrate to customers that every effort has been made to establish the good physiological condition of the seed lots in question.

Incorporation of vigor testing in an in-house quality assurance and control program can reduce complaints and provide a good defense in responding to complaints provided, of course, the company has made and adheres to a management decision not to market seed that fall below certain minimal quality standards.

Research and Development

Vigor tests are especially valuable in the research and development programs of public institutions, seed breeding firms, and seed companies.
Production locations and harvest practices, conditioning equipment, facilities and procedures, storage facilities, and distribution/marketing strategies can be devised, established, monitored, and adjusted as necessary to produce and maintain seed at quality levels that are economically feasible and suitable for the varying needs of customers.

In breeding programs, vigor tests can be used to identify inherent weaknesses in breeding and advanced lines which can lead to seed production and quality problems. Conversely, plant breeders can identify traits which contribute to superior emergence ability of seed under stress conditions.

Summary

Vigor/deterioration are "properties" which have a great influence on the planting value of seed, and its stability from the harvest period to the sowing season. Seed vigor testing, properly integrated in a comprehensive quality assurance and control program, is a major management tool in the seed industry.