THE HISTORY OF SEED VIGOR TESTING[1]

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ABSTRACT

Seed vigor testing has emerged as a routine method to test seeds for field performance capability. This development can be traced to deficiencies in the philosophy of the purpose of a standard germination test. Early terms included "driving force" and "germination energy" of seedlings to capture the concept of seed vigor. Yet, no organized approach to defining seed vigor or developing seed vigor tests was given until the International Seed Testing Association (ISTA) formed the first Biochemical and Seedling Vigor Committee in 1950. The Association of Official Seed Analysts (AOSA) established a Vigor Test Committee in 1961. Both committees provided the central leadership in vigor testing that culminated in the production of respective Handbooks. This review of the history of seed vigor testing focuses primarily on those events which occurred within AOSA since the inception of that first Committee in 1961 and documents the impetus and momentum that led to vigor testing as an accepted measure of seed quality.

Additional index words: **seed germination, seed quality, seed deterioration, seed technology, field emergence.**

INTRODUCTION

The history of seed vigor testing begins with the development of the standard germination test. In 1816, seed legislation was first passed in Berne, Switzerland. It was necessary because unscrupulous vendors of clover seed were adulterating the product with small stones. By 1869, Frederick Nobbe established the first seed testing laboratory in Tharandt, Germany. These pioneering efforts quickly led to the founding in 1876 of the first seed testing laboratory in the United States in Connecticut by E. H. Jenkins and the writing of the first "Rules for Testing Seeds" in 1917.

Development of the Standard Germination Test

These historic milestones illustrate that seed testing is important and has become a routine component of determining the value of seed for over the last 150 years. Of prime importance, of course, has been the assessment of a seed's ability to germinate and produce a normal seedling. This is because successful and rapid stand establishment is often correlated with increased yields and added value of the harvest-

[1] Salaries and research support provided by state and federal funds appropriated to The Ohio Agricultural Research and Development Center, The Ohio State University. Journal article no. 132-93 .

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ed product. This ability has traditionally been monitored by the standard germination test. The Association of Official Seed Analysts defines seed germination as "the emergence and development from the seed embryo of those *essential structures* which, for the kinds of seed in question, are indicative of the ability to produce a normal plant under *favorable* conditions" (emphasis added). Yet, this definition of seed germination and the purpose of the standard germination test do not always provide the purchaser the correct information about a seed lot's stand performance ability. There are, in fact, a number of deficiencies in standard germination test philosophy as it is conducted today. These include:

- The AOSA definition of seed germination emphasizes that the seed analyst must focus on *essential structures* which lead to the production of a normal plant. But, this emphasis on seedling morphology often has little relationship with rapidity of growth, a prime criterion of the potential for successful field establishment.

- Methodology for the conduct of a standard germination test is standardized so that test results are reproducible within and among seed testing laboratories. This process means that *favorable* conditions are utilized as described in the AOSA definition in order that greater uniformity in test results is obtained. Tests must be conducted on artificial, standardized, essentially sterile media in humidified, temperature controlled chambers. These conditions are so synthetic that they seldom relate to field conditions that seeds likely encounter. In essence, because the standard germination test is conducted under *favorable* conditions, it basically establishes the maximum plant producing ability of the seed lot. When field conditions are optimum, the standard germination test values may correctly predict field performance of the seed lot. For the most part, however, standard germination values overestimate actual field emergence. We know, for example, that when the standard germination result is 80%, we might obtain 80% emergence in the field under rare circumstances. In most instances, the field emergence is considerably less.

- The standard germination test is designed to provide a first and final count. The first count has a purpose of basically removing most of the "strong" seedlings that have already germinated. The final count is designed to provide a sufficiently long period that even "weak" seeds are coaxed or provided every opportunity to be considered germinable. The germination percentage, therefore, is the sum of "strong" and "weak" seedlings. The difficulty with such a process is that "weak" seedlings seldom perform adequately when provided environmental stresses associated with field emergence.

- By definition, germination is scaleless. A seed is considered either germinable or it is not. There are no distinctions provided for "strong" or "weak" seedlings. Those considered germinable may vary from weak to robust in field performance. This inability to document the quality of the seed fails to take into account the progressive nature of seed deterioration which has a major impact on stand establishment.

The Definition of Seed Vigor

These deficiencies led to a continuously disquieting murmur for years that not all facets of seed quality were being properly identified by the standard germination test. Initially, it was difficult to agree on what these unmeasured components of seed quality were. In 1911, Hiltner and Ihssen used the term *triebkraft* to imply "driving force" and "shooting strength" of germinating seedlings. In the United States, the early 1930s saw the acceptance of the term "germination energy" to mean the rate or speed of germination. It wasn't until 1950, however, that the landmark International Seed Testing Association Congress held in Washington, D.C., focused on these seed quality attributes. ISTA President W. J. Franck, driven by increasing international trade following World War II, emphasized that international marketing of seeds was difficult because of discrepancies in germination test results between American and European seed testing laboratories. According to Franck, these two locations had differing philosophies about the purpose of a standard germination test. The Europeans believed that reproducibility of test results was most important to assure that seed lots could be sold across national boundaries. The Americans believed that the plant-producing ability of a seed lot was the essential agricultural objective of the germination test. Franck pleaded that both groups needed to come to grips with these differing philosophies. To start the debate, he proposed that germination testing should be conducted under favorable conditions in order that uniform test results be obtained. The plant-producing ability in the field of a seed lot was to be defined by a new term: vigor. In 1950, Franck established the ISTA Biochemical and Seedling Vigor Committee and challenged it with two principal objectives: 1) define seed vigor, and 2) develop standardized vigor test methods.

The development of a satisfactory definition of seed vigor has been central to the objectives of both AOSA and ISTA Vigor Test Committees. Without a definition, the ability to measure or test this undefined entity becomes difficult, if not impossible. Fortunately, many definitions have been proposed. A study of their evolution portrays the initially confusing and changing status in the expectations for seed vigor. At the outset, some suggested that seed vigor was so complex that it could not be reasonably defined. Rather, they believed that the notion could only be captured within the framework of a concept. Still others remained undaunted by the challenge. In 1957, Isely defined seed vigor as "the sum total of all seed attributes which favor stand establishment under favorable conditions." Building on this definition, Delouche and Caldwell (1960) stated that "seed vigor is the sum of all seed attributes which favor rapid and uni-

form stand establishment." Note the subtle differences from Isely's definition. Delouche and Caldwell clarified stand establishment to emphasize rapid and uniform performance, and they also deleted the reference to favorable conditions. It was clear by this point that rapid and uniform field performance were acceptable parameters of seed vigor. However, the reference to the "...sum total of all seed attributes..." still left unresolved what the factors were that determined seed vigor. To address this issue, Woodstock, in 1965, proposed that seed vigor was "that condition of good health and natural robustness in seed which, upon planting, permits germination to proceed rapidly and to completion under a wide range of environmental conditions." Perry, in 1973, identified seed vigor as the "physiological property determined by the genotype and modified by the environment which governs the ability of a seed to produce a seedling rapidly in soil and the extent to which the seed tolerates a range of environmental factors." He clearly emphasized that seed vigor was determined by both genetic and environmental components. By this time, consensus was rapidly emerging on a definition for seed vigor. In 1977, ISTA formally defined seed vigor as "the sum of all those properties which determine the potential level of activity and performance of the seed or seed lot during germination and seedling emergence." In an attempt to more precisely quantify the components of seed vigor, AOSA, in 1980, defined seed vigor as "...those seed properties which determine the potential for rapid, uniform emergence, and development of normal seedlings under a wide range of field conditions." This definition utilized measurable parameters such as rapid and uniform emergence which could be assessed numerically. The development of "normal seedlings" was a criterion with which seed analysts were very familiar. The definition also emphasized the ability of the seed to perform not only in the field, but also under a wide range of field conditions to include both stress and optimum conditions. These definitions clearly differentiated seed vigor from seed germination.

AOSA Progress in Vigor Testing

Meanwhile, after the 1950 ISTA Congress, less attention was given in the United States to discrepancies in germination test results, which were viewed primarily as a European concern. It wasn't until the publication of two articles on seed vigor testing (Isely, 1957; Delouche and Caldwell, 1960) that the key stimulus was provided to refocus and redirect American efforts at seed vigor. Following these publications, the AOSA formed its first Vigor Test Committee in 1961 chaired by Dr. R. P. Moore and consisting of committee members M. Brummitt, T. F. Cuddy, J. C. Delouche, L. Jensen, D. Isely, and G. E. Nutile. The accomplishments of that first committee were to bring into focus the advantages and disadvantages of direct vs. indirect vigor tests, as well as outlining various concepts of vigor testing. It seemed at this point that the challenge of vigor testing was straightforward and solutions imminent. But a review of the historical progress of the AOSA Vigor Testing Committee demonstrates the naivete of this notion. The following represents a chronology of the more important historical achievements of this important committee.

In 1963, Dr. R. P. Moore reported, "Progress has been slow on attempts to reach an agreement on the precise traits to be measured and suitable methods for their evaluation." Three years later in 1966, he stated, "Since quite diverse points of interest are involved, the progress of the Committee could no doubt be promoted by restriction of the assignment to measurement of vigor which commonly conveys rate and magnitude of growth." Clearly, the more the topic was studied, the more challenging it became. By this point, committee members were becoming divided about the meaning of vigor and how best to measure it. For example, Dr. Moore was a staunch proponent of the use of tetrazolium chloride, while others suggested that direct growth measurements were more suitable vigor evaluations.

In 1968, Dr. Lowell Woodstock became chair of the committee. Under his leadership the first vigor test referee was conducted using corn. Laboratories were instructed to use any vigor test of their choice in the evaluation of seed samples. This initial effort was designed more to identify the best vigor tests for this important crop rather than being concerned with standardization of results. In the next five years, the Committee continued to evaluate seed vigor definitions and began to define a variety of vigor tests. During this period, greater and greater attention was being given to seed vigor, as yet an untested, unmeasured, and needed component of seed quality. By 1974, the clamor for vigor tests was so loud that the Association of American Seed Control Officials (AASCO) formally resolved that AOSA develop standardized seed vigor test procedures. This resolution prompted the AOSA Vigor Testing Committee to even greater activity. The committee broadened its membership from a small regulatory group to 12 members that now included university and seed trade personnel. It convened a special 1974 meeting in Little Rock, Arkansas, to address the AASCO resolutions. At that meeting, it was decided that a vigor testing handbook providing specific vigor test procedures, was a major objective. However, an important early conclusion was that a deliberate approach to vigor testing was necessary to avoid hasty use of vigor tests that were still not yet standardized. To accomplish this, eight vigor test procedures were identified for a special publication edition of the AOSA Newsletter. Rapid progress was now being made in vigor testing. Woodstock wrote in 1974, "There has been more real movement towards consensus in seed vigor testing and more real progress by the AOSA Vigor Testing Committee in meeting its responsibilities for developing, evaluating, codifying, and standardizing vigor testing procedures during the past nine months than during any recent period." Under Dr. Woodstock's leadership, the "Seed Vigor Testing Progress Report" was published as a special issue of the AOSA Newsletter (Woodstock, 1976). At that time, Dr. Miller McDonald became chair of the committee.

The "Progress Report" was a significant milestone in vigor testing. It provided specific guidelines for vigor tests that could be evaluated using a "referee" format. The Vigor Testing Committee immediately set out to determine the standardization of these procedures and to improve them so that they were repeatable among laboratories. Corn and soybeans served as the first crops receiving greatest emphasis. McDonald stated in 1977 that another important and concurrent Committee objective was to "derive a satisfactory

definition of seed vigor" because the definition would ultimately determine what a vigor test would measure. By 1980, a seed vigor definition had been approved by AOSA, AOSCA, ASTA, SCST, and AASCO. During that same period, the Committee was convinced that it had developed viable vigor tests and was committed to their publication in a handbook. Seven vigor tests were written and published in 1983 as the AOSA Seed Vigor Testing Handbook. These included (authors in parentheses) accelerated aging (Charles Baskin), cold test (Ben Clark), cool germination test (Gurnia Moore), conductivity (Kar-Ling Tao), seedling vigor classification (George Spain), seedling growth rate (Joe Burris), and tetrazolium (Charles Baskin). The Committee further decided that the average user of seed vigor tests required additional educational background concerning this "new" topic. To accomplish this, the Handbook was divided into two parts. Part I was entitled "Seed Vigor: Its Meaning and Importance" and provided a historical context of vigor development, the definition of seed vigor, types of vigor tests, and the applications of vigor test information. Part II was composed of suggested procedures for the seven vigor tests. It was printed in a loose-leaf style similar to the "Rules" to accommodate subsequent changes in procedures. The unusual appearance of the Handbook included a black cover with white lettering. These colors were selected because the Handbook represented the philosophical movement of a subject that had been previously considered as vague and gray to one that was well-defined in "black and white" terms. The cost of the Handbook to the Association was $6.00/copy and the sale price was established at $20.00/copy.

With the publication of the Handbook in 1983, Dr. Dennis TeKrony became chair of the committee. In 1984, under his capable leadership, the objectives of the committee were defined as: 1) to improve test procedures in the Handbook (move from "suggested" to a new category called "recommended" procedures) and 2) to broaden the range of species covered. In addition, an educational pamphlet "Understanding Seed Vigor" was published. This pamphlet was a four page, lay summary of seed vigor that could be easily understood by the agricultural community. During this period, the committee aggressively pursued standardization of its most promising vigor tests: accelerated aging, conductivity, and cold tests. By 1987, the accelerated aging test was significantly revised and improved and became the first vigor test for soybeans to be moved from the "suggested" to "recommended" vigor test section. During this same year, over 1,000 copies of the Handbook were sold. In 1989, revisions of the accelerated aging, conductivity, and cold test procedures were completed and published. With Increasing reliability and standardization of the tests, the committee set out to evaluate tolerances for vigor test results. This first evaluation was completed in 1991. At that time, the committee began evaluation of the cold test for other crops besides corn.

Dr. Jan Ferguson became the fifth chair of the committee in 1991. The committee continued to focus on the movement of the most reliable vigor tests into the "recommended" vigor test section. In 1993, the "Understanding Seed Vigor" pamphlet was updated and published. A major future objective of the committee remains an effort to expand vigor tests into other crops beyond those with traditional agronomic focus.

The AOSA Vigor Testing Committee has provided effective leadership in the United States and Canada in this important seed quality testing area. Its historical success can be followed by monitoring the number of laboratories routinely using vigor tests. In 1978, 52% of laboratories were conducting vigor tests (Table 1). Just twelve years later (1990), 75% of the seed testing laboratories were using one or more vigor tests. These data indicate that the committee not only provided useful vigor testing protocols but has also educated the users so that the value and limitations of vigor testing are fully understood.

CONCLUSIONS

Let us return to the AOSA 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." The focus, of course, is on field performance, a parameter of equal importance to the consumer of seed as well as the seed industry. Today, every major seed company is acutely aware of and tests seeds for vigor. The seed consumer or farmer is yet to be routinely provided this valuable seed quality information. As important as this seed quality component is, and in view of the significant historical progress we have made, it remains perplexing that there is an apparent posture that only seed companies can use, benefit from, and understand the importance of seed vigor. This certainly is not true and we should strongly endorse the notion that the seed consumer can also use, benefit from, and understand the importance of seed vigor when purchasing seeds. The past of course is past, and while interesting, we should not belabor its importance.

The AOSA Vigor Testing Committee is to be commended for its great strides in vigor testing made from that very first meeting back in 1961. It provided the genesis of a concept of vigor testing to a term that is now fully defined. Vigor testing is no longer composed of a suite of direct and indirect tests, but test protocols that are explicitly stated in the AOSA Vigor Testing Handbook. Some of these — accelerated aging, conductivity, and soon the cold test — have moved from "suggested" to "recommended" procedures; a change in status that reflects the committee's perception that these tests are standardized. In that effort, considerable cooperation between AOSA and the seed trade in defining seed vigor test procedures has been made and reaped immense benefits. Over 75% of today's seed testing laboratories routinely conduct one or more vigor tests. Despite these important achievements, this information has yet to be routinely provided to the consumer. While development of new and refinement of old vigor tests will be a continuing responsibility, this charge—permitting the seed purchaser the opportunity to read and evaluate vigor test data—remains the future and most challenging role for the Chairs of the AOSA and ISTA Vigor Test Committees.

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