The Science of Seed Testing

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Adulteration of seed used to be fairly common. Crop seeds were mixed with other kinds of less expensive seed or inert material so like the desirable seed that they were hard to detect.

Some European seedsmen screened and stained sand to the size and color of clover seeds, with which they mixed it. Expensive seeds, such as cauliflower, were adulterated with less expensive kinds that could not be distinguished by seed characteristics. Factories existed in England in which the adulterants were devitalized to avoid detection. To stop them, Parliament adopted the Adulterated Seeds Act in 1869.

We have many records of seed adulteration in the United States during 1890–1915. Common examples include sweetclover and black medic in alfalfa and red clover; Canada bluegrass in Kentucky bluegrass; and perennial ryegrass in meadow fescue or vice versa, depending on the difference in prices.

Screenings containing relatively high percentages of weed seeds were frequently used as adulterants.

Seeds of dodder, a parasitic pest, were such a common impurity in forage seeds that western European countries, Canada, and Argentina legislated against the practice. An examination of 873 samples of red clover and alfalfa seed by the Federal seed laboratory in 1906 showed that 30.6 percent of the samples contained dodder.

Analyses of 61 samples of low-quality red clover seeds imported into the United States in 1905 and 1906 revealed averages of 30 kinds of weed seeds per sample, 3,088 weed seeds per
ounce, 74 percent of pure seed, and
dodder in 75 percent of the samples.
The sale of low-germinating seeds or
dead seeds in Europe and America
added to the uncertainties of crop
production. The average germination
of 12,454 packets of vegetable seeds
collected from commission boxes and
tested by the Federal seed laboratory
in Washington from 1907 to 1910 was
60.5 percent. Mail-order seed was
somewhat better; 6,117 samples pur-
bought in 1911 gave an average germi-
nation of 77.5 percent.

These and other unscrupulous prac-
tices stimulated the study of seeds in
many countries and States and led to
the establishment of laboratories where
seeds could be tested.

The first station for testing seed
was established at Tharand in Saxony,
Germany, in 1869, under the direction
of Friedrich Nobbe.

E. Möller-Holst was planning a pri-
ivate seed-testing station in Copen-
hagen, Denmark, at the same time. It
opened in 1871 and later was sup-
ported by public funds. By 1904, there
were more than 130 seed-testing sta-
tions outside the United States.

Some farsighted men in the United
States saw the need and began studies
and examinations of seeds before the
adoption of seed laws or establishment
of seed laboratories.

The first laboratory for the examina-
tion of seed in this country was estab-
lished at the Connecticut Agricultural
Experiment Station in 1876 by E. H.
Jenkins, who had studied in Germany
and spent some time with Dr. Nobbe.

Seed testing was well established by
1900 in the U.S. Department of Agri-
culture, Connecticut, Maine, Massa-
chusetts, Michigan, New York, and
Vermont. Within the next 10 years,
at least 10 other States were testing
seeds. The Federal laboratory gave
impetus to this movement by the es-
ablishment of several cooperative Fed-
eral-State laboratories in the South,
Middle West, and Far West.

Forty-four States were operating

Factors of seed quality include: Per-
centages of pure seeds, other crop seeds,
weed seeds, and inert matter; percent-
ages of germination and hard seeds
when present; the rate of occurrence
of designated seeds of noxious weeds;
varietal purity; freedom from disease
and disease organisms; moisture con-
tent; origin of production; and test
weight (the bushel weight, hectoliter
weight, 1,000-seed weight).

The chief aim in testing seeds is to
assess the value of each sample or lot
of seeds tested in accordance with the
quality factors. Successful testing for
them requires adequate facilities, a
trained staff, uniform methods or pro-
cedures, and a research program that
looks to the improvement of methods
and procedures.

In developing standard testing pro-
cedures, primary consideration is given
to providing methods by which ac-
curate and reliable information may
be obtained. This is essential if the
test results are to be of value to the
planter.

The second consideration is to pro-
vide methods by which uniform results
may be obtained.

Because seed is a commodity of com-
merce, the testing procedures have to
be standardized to the extent that results
obtained on a sample in one laboratory
can be repeated within
accepted tolerances by another labo-
atory. Whether the original test is
made by a private, commercial, State,
or Federal analyst, the seed lot may
be tested again in a distant State or in a foreign country. Financial transactions in seed, movement of seed in domestic and international commerce, and administration of seed laws would be greatly handicapped without confidence in the test results.

Finally, the methods must be practical. The degree of accuracy and uniformity of the results and the number of samples that can be tested are limited by the equipment and amount of work required in making the test, the number of days before the results are available, the kind of seed, and how well the seeds have been cleaned.

The methods of testing seeds have been published under different titles and by various institutions and organizations and are referred to as rules.

The first rules in North America were prepared and published in 1897 in a circular entitled, "Rules and Apparatus for Seed Testing," by the Department of Agriculture as unofficial guides for seed analysts.

They specified the minimum size of samples for purity analysis and provided general instructions for making tests of germination. Equipment used for testing at that time was described and illustrated.

The publication was revised and expanded in 1904 to include methods of sampling seed lots, give more specific methods of testing for purity and germination, define the components of the purity analysis, and to specify the conditions for testing 63 kinds of agricultural and vegetable seeds for germination.

A group of persons from 16 States, the Department of Agriculture, and the Canada Department of Agriculture met in Washington, D.C., in 1908 to consider uniform methods of testing seeds and a model seed law. They formed an organization, which they named Association of Official Seed Analysts of North America. (It was shortened in 1939 to Association of Official Seed Analysts.)

One of the main functions of the association has been the preparation and adoption of official rules. Publication of the rules adopted by the association dates from 1917. Revisions since have been published by the New York Agricultural Experiment Station, the Department of Agriculture, and the association.

The Federal Seed Act of 1939 instructed the Secretary of Agriculture to develop and publish procedures for testing seeds to be used in the administration of the act. Consequently, appropriate procedures were published in 1940 as a part of the Rules and Regulations Under the Federal Seed Act.

Revisions were made in 1946, 1950, 1956, and 1960.

The commercial seed analysts, through their organization, the Society of Commercial Seed Technologists, also assist in the formulation of the rules. To avoid conflict between the two sets of rules, Federal employees take part in the development of the rules of the Association of Official Seed Analysts. The amendments adopted by the Association of Official Seed Analysts are then incorporated as far as possible into the regulations under the Federal Seed Act.

To take advantage of developments in seed testing, the rules have been revised at least every 5 years since 1940. Amendments and minor revisions can be made each year if necessary. The association maintains a standing committee to review research data and other information that may lead to improvement in the rules.

Members of the committee are persons from the State seed laboratories, the Department of Agriculture, the Canada Department of Agriculture, and the Society of Commercial Seed Technologists.

The International Rules for Seed Testing provide uniform methods of evaluating the quality of seeds moving in foreign commerce. These rules, first published in 1931 in English, French, and German, have been revised five times. Before 1950, there were some important differences between the North
American rules and the international rules, but the major differences were compromised in 1953.

Many countries now use the international rules when testing for both domestic and foreign purposes. When requested, seed-testing stations belonging to the International Seed Testing Association sample seeds intended for foreign commerce and test the samples by the international rules for the issuance of certificates of quality.

Most of the research on methods of testing seeds in this country has been done in the Federal seed laboratory and a few State laboratories, where testing is part of the agricultural experiment station or the agricultural college.

A research project on sampling and testing seeds was inaugurated by the Federal seed laboratory in 1948 under the Research and Marketing Act of 1946. Varying amounts of research on methods have been conducted since then in the Department. Much of the research conducted by the State agricultural experiment stations since 1956 has been coordinated on a regional basis.

The problems in seed technology are so numerous that a strong research program is needed. The nature of the problems calls for the services of specialists in the various disciplines of plant science as well as chemists, physicists, and engineers.

A well-balanced research program should seek to improve methods of testing, investigate the possibility of adapting new information or principles, and conduct research on which new methods of testing or evaluating quality can be based.

Research on seed purity has dealt primarily with three types of problems.

The first type relates to specifying differences between crop and weed seeds and inert matter, which in seed testing is any material other than seeds.

An illustration is wild garlic (Allium vineale) and wild onion (A. canadense), which are common in lawns, pastures, and hayfields. The aerial bulblets of wild garlic and wild onion, which function as seeds, often are found in agricultural seeds. It was known that the larger, undamaged bulblets could produce plants, but there was suspicion that the small, dry bulblets were dead. It was demonstrated that the small, desiccated bulblets and large bulblets, damaged at the basal end, are not viable. Acceptable methods of making separations have been developed.

The second type of research is illustrated by mechanical methods of separating inert matter from pure seed. In the grasses, a seedlike structure, consisting of either glumes and flower parts or glumes and a mature seed, is called a floret. The separation of filled and empty florets by conventional methods is difficult. Research on seed blowers and standard blowing techniques reduced considerably the time and tedious required to test some chaffy grasses. When testing seed by the standard blowing procedure, the blower is calibrated by using a prepared standard sample of the kind of seed being tested, in which the heavy and light seeds are stained opposing colors. The blower setting to be used is determined by blowing the standard sample until the best separation is obtained. This method has been adopted by the Association of Official Seed Analysts for testing seed of Kentucky bluegrass.

The third type of research in testing for purity is seed identification. Considerable attention has been given to illustrations, keys, and descriptions of seeds to aid in identification. Because of the minuteness of seed characteristics used for identification purposes, keys and descriptions by themselves are usually not sufficient. Photographs of seeds usually fall short of desired results.

Good, accurate drawings of seeds that can be duplicated by photography usually are better than direct photographs of the seeds. The plates prepared by Department of Agriculture workers, F. H. Hillman, Helen H. Y. Yearbook of Agriculture 1961.
Henry, Albina F. Musil, and Regina O. Hughes, are well known.

A combination of keys, descriptions, and plates, supported by a good seed herbarium, provide excellent facilities for identifying seeds.

As commerce in seeds has expanded over the years, the number of kinds that the analyst must identify has increased greatly. This is particularly true in a country having such a vast range of growing conditions as the United States. The importation of seeds from many parts of the world has magnified the problems in identification of seeds.

Research on germination has been concerned largely with dormancy. A seed that does not germinate in a properly conducted test may be alive or dead. If it is alive, it is dormant.

Because many kinds of crop seeds are dormant when tested, considerable research has been concerned with finding practical methods of evaluating samples with dormant seeds. Cereal and grass seeds have been the subject of many of these investigations. Samples suspected of dormancy are frequently tested by the method for nondormant seeds and the method for dormant seeds. Duplicate testing in this way is expensive; testing by only one method may give incomplete germination.

Unless there is a fair degree of correlation between germination tests in the laboratory and field stands, the germination test would have little value.

In the early days of seed testing, practically any seed that produced a radicle—first root—was regarded as having germinated.

Tests conducted in the Federal seed laboratory by W. L. Goss as early as 1915 showed that weak and defective sprouts did not develop into plants. Laboratory results from 292 samples of crimson clover seeds were 10 percent higher than results in the greenhouse. It is likely that differences between laboratory and field tests would have been greater.

Considerable research in the United States and Canada since that time has gone into evaluation of seedlings. More research has been conducted on the garden bean than on any other single crop. The research has been fruitful in that it has resulted in classifying as abnormal the seedlings that are weak and defective. It also has led to the establishment of specific guides for the separation of normal and abnormal seedlings. Problems remain, however.

The time seeds need to germinate is an important consideration. The germination of radish seed usually is complete by the end of the fifth day of test. Some grasses require up to 42 days for completion of the test. Reduction of the test period would be desirable. Determination of viability by chemical tests, acceleration of germination at increased temperatures, stimulation with chemicals, and excision of embryos have been investigated as means of making quick tests. No completely reliable method of determining viability by quick tests has yet been developed.

The planting value of hard seeds in a few leguminous crops has been studied. Seed analysts do not have to concern themselves with the value of hard seed, but they must determine the number of hard seeds that may remain at the conclusion of the germination test.

Varying numbers of seeds of some grasses are so dormant when tested that they fail to germinate by established procedures. Dormant seeds are alive, but little information is available about their planting value. To evaluate seed lots containing dormant seeds properly, analysts and control officials alike need to know more about the planting value of firm, ungerminated seed in different crops.

Research on factors of quality of seeds other than purity and germination has been limited.

Some research on the vigor of corn has led to a method of detecting weak lots which may result in crop failures under adverse weather and soil conditions. Attempts at developing a vigor test for garden peas have been less successful.
Additional information is needed on methods of determining variety by examination of seeds and seedlings. Growing tests are expensive to make, and the value of the results often drops in proportion to the time required to complete the tests.

Improvements of methods of determining the kind and incidence of disease organisms on seeds and ways to detect seed treatments are needed. We now have greater understanding with respect to the use and application of tolerances to test results. It is not likely that two samples drawn from the same seed lot or from a larger master sample will be exactly the same. Replicate test results consequently can be expected to vary. The variations can be calculated and are called tolerances. Early tolerances were little more than estimates, but statisticians have been working on them over the years to put them on sound statistical bases.

Differences in test results on the same lot of seed often can be traced to lack of uniformity among the different bags. Seedsmen have been informed of their responsibility in this connection, and research agencies are seeking methods by which seed lots can be reliably mixed to uniformity.

Statisticians have developed minimum latitudes of variation between bags for the different quality factors, making possible homogeneity tests by which bag-to-bag variation can be determined. The principal weakness in this procedure is the large amount of time required to make tests on individual-bag samples.

The education and training of seed analysts depend on several factors, including the number and kinds of crop seeds the analyst is expected to test, the area from which the seeds come, the kinds of tests they are expected to make, and the supervision they have.

Analysts in large laboratories often work under supervision and are expected to perform only one phase of testing, such as tests of purity or germination. Analysts in some small, private laboratories must be prepared to make various tests on any submitted sample, without supervision. Various intermediate arrangements exist.

Analysts who must assume the responsibility for the tests should have earned at least a college degree in one of the plant sciences, preferably botany. After his college training, the prospective analyst should work under the guidance of an experienced technician. Analysts having less responsibility and working under direct supervision may not need the college background; without it, however, the chances are greatly reduced that the analyst will be able to cope with new and difficult situations.

Many a seed analyst has received his basic training by working as an apprentice under an experienced technician, completing all or part of a college education, followed by supervised laboratory experience, and studying seed testing while working toward a degree.

In large laboratories, where specialization is possible, the purity analyst should have a working knowledge of plant taxonomy and some familiarity with the plant diseases that may be detected on dry seeds. The purity analyst must know a large variety of crop and weed seeds, including the variation in characteristics of the commonly tested crop seeds and associated weed seeds. Through experience, the analyst learns the differences between seeds and inert matter in species that produce empty seeds.

The germination analyst should have training in plant physiology and a familiarity with symptoms of plant diseases. Alertness and an awareness that low germination may be the result of improper testing are prime considerations. He must recognize dormant seeds in the test, as distinguished from dead seeds, and use methods that will promote germination. Testing for variety, health of seed, seedling vigor, and moisture content requires the services of persons who have had spe-
cial training in the area of work to be undertaken.

C. H. Lawshe and L. E. Albright, of Purdue University, developed tests for the selection of purity analysts by measuring adaptability, manual dexterity, and visual acuity. The tests are described in a 14-page brochure published by the Purdue University Agricultural Experiment Station, Lafayette, Ind., under the title, "A Manual for the Selection of Competent Seed Analysts."

Training programs have been instituted at Iowa State University, Mississippi State University, Oregon State College, and Purdue University. Before 1940, many supervisors in Federal, State, and commercial laboratories received their training at the Federal seed laboratory in Washington, on an apprenticeship basis. From 1940 to 1950, Federal analysts conducted regional, 1-week short courses at State and Federal laboratories. This in-service instruction was open to all analysts working in State, commercial, and private laboratories. Demands became so great that in 1951 a Federal employee was assigned full time to instruction work. Short courses have been held throughout the country.

Laboratories for testing seeds may be Federal, State, commercial, or private.

There are Federal laboratories at Beltsville, Md., New Brunswick, N.J., Montgomery, Ala., Kansas City, Mo., and Minneapolis, Minn. There is a Federal-State laboratory in Sacramento, Calif. These laboratories are maintained to administer the import and interstate provisions of the Federal Seed Act. They also conduct a limited amount of testing for the import and export trade and for Government agencies.

All States but three operate one or more seed-testing laboratories, which exist primarily to implement the administration of State seed laws and to test samples for farmers and seedsmen. Commercial seed laboratories test samples received from any person who desires the service on a fee basis. Some commercial laboratories have standing contracts with seed firms. There are about 30 such laboratories in the country.

Many seed firms maintain their own private laboratories to perform testing services incidental to their operations. Most employ one analyst, but a few are large enough to permit specialization of work.

Three organizations have helped to further testing in the United States.

They are the Association of Official Seed Analysts, whose members work in Government laboratories in the United States and Canada; the International Seed Testing Association, whose secretariat is in Europe and whose members are national governments; and the Society of Commercial Seed Technologists, whose members are Americans and Canadians.

The main objectives of the three organizations are basically the same: The development and adoption of standard methods of testing seeds, promotion of research leading to the improvement of seed testing, and exchange of information through meetings and publications.

Since 1950 the Association of Official Seed Analysts and the International Seed Testing Association have worked closely together. The differences that previously existed between the American-Canadian Rules and the International Rules have been largely eliminated. A realization of the need for uniform testing procedures on an international basis and a willingness to compromise differences have made this possible.

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