OPPORTUNITIES FOR PROGRESS
IN SEED GERMINATION TESTING

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Nearly 100 years have passed since Professor Nobbe established seed testing as an agricultural practice in Germany in 1869. It has been 71 years since the publication of the first set of rules for seed testing in the United States in 1897 (11). In the early days, a seed test was a safeguard against stovepiping, adulteration with glass beads, and other types of fraud. Many of these unethical practices have long since been eliminated and seed testing today can serve other purposes.

The increasing complexity of agriculture and the need for information on the performance potential of seed requires that more complicated considerations be made in determining seed quality. In addition to germinability, the seed industry and farmers now need information on total viability, potential stand establishment value, uniformity, storability, and any loss of yield potential attributable to seed deterioration.

The technical procedures followed by all laboratories are codified in the Rules for Testing Seeds, published by the Association of Official Seed Analysts. These Rules are improved and modified at intervals, currently every five years. This is good. The 112-page 1965 edition of

Journal Paper Number of the Mississippi Agricultural Experiment Station.
The Rules (2) stands as testimony of the industriousness of the current and previous Rules Committees.

But—-is seed testing adapting fast enough to keep pace with the rapidly changing agricultural technology that now includes narrow rows, precision planting, starter fertilizers, preemergence herbicides, new varieties, numerous types of seed treatments, and once-over harvesting? It is discouraging to find that recent revisions of the Rules have failed to incorporate important advances in knowledge, especially in the field of seed physiology. As a result, progress in seed testing has lagged behind that of other agricultural technologies which are extremely eager to incorporate immediately each new development that proves advantageous and profitable.

Rules changes are normally made on the recommendation of individuals who have studied various testing methods for a particular species with regard to temperature, light, and duration of test. Occasionally someone, through intensive research on a particular species, recommends an extreme modification of a method and the method is adopted for this species, and this species only. As a result, the Rules have grown piecemeal, with exceptions here and exceptions there, with appendices here and appendices there. Under the present system of revising the Rules, prospects for improving the situation are not too good.

It is time to consider an intensive review of seed testing procedures and traditions. Methods which were adequate two decades ago no longer seem so. There is a great need to update the technology of the
member laboratories of the AOSA and the SCST.

Inadequacies of the Rules

An intensive review of the Rules should consider the following problem areas which now exist:

1. **Incorporation of new research findings.** We have not incorporated new research findings into germination testing methodology. The methods now used are essentially the same as the original ones used in 1904 (11). To be sure, the test duration has been changed on some kinds, changes have been made in temperatures here and there, but we have taken absolutely no advantage of knowledge of the phytochrome system, the action of auxins, hormones, growth regulators, inhibitors, and increased oxygen tensions on expression of germinability.

2. **Inconsistent germination testing procedures.** Germination testing procedures have become inconsistent between species with similar germination characteristics. This is especially true for kinds which exhibit dormancy. Just a few examples from Table III of the Rules to illustrate the problem of inconsistency:

   a. Provision is made for promoting germination with potassium nitrate, but not with any of several other chemicals known to promote germination.

   b. Provision is made for promoting germination of gourds and all varieties of Bahiagrass except Pensacola by rupturing the seedcoat. This procedure is not prescribed, however, for any other kinds with similar types of dormancy.
c. Provision is made for applying fungicide protection on China aster and cornflower, but not on any other species which may be susceptible to molds.

d. Provisions are made for reporting the percentage of dormant seeds if dormancy is due to hard seed coat, but not from other causes.

3. Prolonged test periods. The fast-moving pace of the seed industry cannot stand for the 3, 4, or 6 week or even longer testing periods required to allow germination of dormant and weak seeds. Most test periods are in multiples of seven--7, 14, 21, etc.--days, which, I suspicion, is for the convenience of the analyst rather than for the seeds.

4. Uniformity of test results. There are still problems in obtaining uniformity of test results as shown by numerous referee tests conducted by the Association.

5. Compromise on testing procedures. Rules are now a compromise between testing for labeling purposes and testing for field performance. While it is said that seeds are germinated under optimum environmental conditions, we have super imposed on these arbitrary testing conditions a system of seedling evaluation that is based on the presumed chances for success in the field. The two are hardly compatible. Thus, the level of optimacy chosen lies somewhere between optimum and field conditions - an arbitrary, inconsistent, ill-defined, shifting line--optimum for some species or conditions, sub-optimum for others.

Outmoded Concepts

'Why have these problems developed? Why aren't we incorporating
new research findings into our Rules? Why are the Rules inconsistent in many places? Why are there still problems in obtaining uniform test results?

I believe the answer can be found by re-examining the basic precepts upon which the Rules are based. If changes are needed, we should throw away the sacred cows that hold back progress. Some of the outmoded concepts as I see them are as follows:

Sacred Cow No. 1: That methods of breaking dormancy should be "naturalistic". Prechilling and KNO₃ are approved methods of breaking dormancy because these occur naturally in the soil. Other possible methods are looked upon by the Rules makers as artificial and unnatural since they are not factors of the field environment. It seems to me that the restriction of naturalistic methods was removed the minute blotters were adopted as a germination substratum. Gibberellins should no longer be considered an artificial factor since they are now considered to occur universally in seeds. The concept of naturalistic methods has prevented the incorporation of new methods of breaking dormancy and has retarded progress in seed testing.

Sacred Cow No. 2: That germination tests are conducted under optimum conditions. Although it is often said that the methods of testing chosen are optimum for each particular species, a systematic inspection soon shows glaring inconsistencies: while temperature and moisture
conditions may be close to optimum, other factors are not. An artificial medium is usually considered to be more optimum than soil conditions, yet it can be shown that artificial media restrict geotropic response of roots, prevent dispersion of inhibitors, and allow the spread of molds under crowded conditions, all of which do not occur in the soil. As long as molds are not controlled and as long as dormancy is not completely broken, we cannot consider that the environmental conditions provided are optimum.

Scared Cow No. 3: That rigid arbitrary rules assure precision of results. There appears to be a feeling that uniformity in test results would be easier to achieve if only one testing method were used for each kind of seed (3). As we look at the Rules as they have been developed over the years, they seem to have become more rigid and inflexible: The 1937 Rules (1) list the duration of germination for an average sample; the present Rules say the final count must be made on the day specified. The early Rules state that the analyst may use his experience and judgement in choosing a germination method for unusual samples; the present Rules are more vague about this. In practice, under the pressure of large numbers of samples to test, the Rules are usually followed without deviation.

It should not be expected that germination tests on all samples of a given species will be successful when using the same germination methods, especially if several months elapse between tests. Being biological entities, seeds are constantly changing and react differently to environmental conditions, depending on their physiological condition. As
I. Introduction

Munn (9) once so aptly put it, "all samples do not fit the Rules and the Rules do not fit all samples" and further, "objectivity is too often subordinated to official Rules." Nutile (10) has said, "The analyst should call into play his experience and initiative when testing the sample which will not respond to the Rules. There should be more flexibility in the use of germination environments. Seeds do not always respect our Rules and you cannot turn a seed analyst into a robot."

Joseph (6) found that optimum temperatures for germination of parsnip seeds varied with the condition of the seed. Freshly harvested seed germinated equally well at all constant and alternating temperatures between 15° and 27°C. When stored 3 years under favorable conditions, the optimum temperature was an alternating 15-25°C. When stored 3 years under unfavorable conditions, the optimum temperature was 15°C. In how many other species does changing specificity to temperature occur as seeds age?

The environment under which seeds mature may affect their germination requirements. For example, Koller (7) found that germination of lettuce seed which had matured at higher temperatures was greater at 26°C than that of seed matured at lower temperatures. Also, germination of seed matured under long days was higher than seed matured under short days. If environment has this effect on lettuce, it probably affects other crops to some extent also. It is easy to see how a rigid rule may lead to a lack of precision due to the differing physiological condition of seed lots.
It is extremely difficult, with an arbitrary method, to obtain precision in testing seed lots in an afterripening condition. For example, a lot of western wheatgrass may germinate 60% in March, but 80% the following October when tested by the same method. Furthermore, if the viability is 95%, no two tests are likely to give the same result until all dormancy is gone. Would not the cause of precision be advanced if the analyst were allowed to use any method at his command to break dormancy? The only place where precision can be absolute is at maximum viability, not where germinability is variable.

Sacred Cow No. 4: That determination of germinability is more important viability. Seedsmen have shown that they desire more than precision in germination testing. Recent activity in tetrazolium testing, firm seed interpretation, etc. is proof of this. Laboratories can be very precise in reporting 9% germination in a dormant lot of green needlegrass or verbena, but it's hard to buy and sell seed on the basis of this kind of information.

The importance of determining true germination potential (viability) of dormant seed lots is pointed out by Pierpoint and Jensen (8). They state that a seed lot of Kentucky bluegrass having a germination of 85% would bring about 5¢ a pound more than one showing 83%; likewise, 90% germinating seed is considerably more valuable than 88%. While seed analysts feel it is not logical to place such a high price differential on such a small germination difference, buyers use the system and it is
essential that every attempt be made to obtain complete germination of all lots tested.

The early Rule-makers, acting on the basis of information then available to them, made it permissible to break dormancy by means of KNO₃, prechilling, and light. The total viability is determined for seeds that respond fully to these treatments, but not for seeds that do not respond. Thus, I feel it has always been the intent to determine total viability, but the Rules contain so many restrictions that this is not always possible.

Sacred Cow No. 5: That rule changes must be based on specific data. Changes in methodology are normally not allowed unless research data are provided to show the advantage of the proposed change. This again leads to inconsistencies since only the well-researched species are subject to changes in methodology.

Oats is a good example of a well-researched species. The Rules provide for 18 separate and distinct methods for germinating this relatively easy-to-germinate seed. Right next to it in the Rules, tall oatgrass may be germinated by only one method.

I am sure many Rules changes could be made by inference just as well as by data. For example, wouldn't it be logical to expect a benefit from rupturing seedcoats of species other than gourds and Bahiagrass? Wouldn't species other than Centaurea be expected to benefit from fungicide protection without research data? With so little organized, supported
research in seed testing, how long do you suppose it would take, under
the present system, to obtain the necessary detailed research to support
Rule changes needed to remove all the inconsistencies between methods?

Sacred Cow No. 6: That the purpose of the seed test is to deter-
mine the value of the seed for planting. This precept is clearly stated in
the introduction to the Rules. But I submit, regardless of the purpose stated
in the Rules, a purity and germination test do not determine the value of
the seed for planting. The seed test merely tells the composition of the
seed lot and the percentage of seeds expected to make plants, and this
serves as a good basis for labeling and law enforcement. Evidence is
rapidly accumulating, however, that seed lots of equal germination may
result in different sizes of harvest (5).

To be sure, some of our seedling interpretations are calculated
to provide information to stand potential, but only under optimum condi-
tions and again only for a few well researched species. The interpretations
are usually made only on morphological and pathological bases, and not
on physiological bases which may be very important in terms of yield
potential.

New Concepts for Testing

It is possible for development of the seed testing Rules to pro-
ceed as at present through periodic piecemeal revisions of methods. But
this type of Rules may fall short of providing the types of analyses required
for tomorrow's sophisticated agriculture.
The Rules should be reappraised with a view toward the requirements of the future. A set of precepts should be established to give consistency and direction to development of seed testing methodology. I would suggest these:

1. **Methods should result in determination of viability, rather than germinability.** Only then can seed lots be accurately evaluated; only then can precision be fully attained.

2. **Tests should be completed within 14 days.** This can be achieved only through a no-holds-barred approach -- use of chemical stimulants, excised embryo techniques, tetrazolium.

3. **Separate testing systems may be needed: one to obtain information for labeling purposes, another to evaluate planting value.** For labeling purposes, it is necessary to determine the percentage of seeds able to develop into plants. For planting value, it is necessary to determine performance potential. The philosophies upon which these two testing systems are based are entirely different, and if we continue to try to make one system accomplish both ends, we may end up with a system of Rules that is unworkable. We should not expect the germination test always to accurately measure field performance.

I wonder if we are all together on the purpose of seed testing? I know from discussions with many persons that there is a diversity of opinion as to the objectives of seed testing. I believe that formal conversations should be undertaken between seeds analysts, seed control officials,
agronomists, farmers, and seedsmen to arrive at a consensus as to the purposes of seed testing. From such joint discussions, the previously suggested guidelines could be evaluated and others proposed.

Specific Recommendations

In order that seed testing may develop according to the guidelines suggested, I offer these specific recommendations for modifying the Rules:

1. Apply the findings of basic research in seed physiology to germination testing procedures. New knowledge should be applied as rapidly as feasible; every five years is not fast enough. These applications will include knowledge of the photochrome system, the action of auxins, hormones, growth promoters and inhibitors, and the effect of oxygen concentration. One distinct possibility might be the substitution of gibberel-lin treatment for the 5-day prechill in freshly harvested oats, wheat, and other crops, cutting 5 days off the testing period (4).

I am sure that in many instances, the prechill is not the best way to overcome dormancy. On fresh, vigorous seed, the prechill is satisfactory. On older, weaker seed, the prechill may actually cause a decline in germination. Then consider what might happen to germination percentages when a blend of vigorous and weak seeds of Kentucky blue-grass is prechilled!

An aggressive effort should be made to help identify new advances in scientific knowledge and consider the application of such new knowledge to seed testing.
2. Specifications should be developed for acceptable ranges of temperature, light, and humidity inside of germinators. Manufacturers need this information in developing new equipment. The present arbitrary standards that germinator developers have chosen are not based on research data and may be unnecessarily strict. We need to know, for example, if seeds will germinate just as well as $25 \pm 3^\circ C$ as at $25 \pm 0.5^\circ C$. The relative refinement of controls affects the cost of equipment tremendously.

3. Encouragement should be given to development of improved germination testing methodology to lessen the amount of human effort involved. One objective should be the elimination of the task of removing seedlings individually from germination tests with a tweezers. Analysts' time could better be diverted from methodically plucking seedlings to problem solving.

4. The Rules should be made consistent. If pricking the pericarp is allowed for breaking dormancy of Bahiagrass, it should be allowed for sand dropseed. If fungi may be controlled with fungicide on Centaurea, it should be all right to apply fungicide to Cyclamen as well.

The goals suggested will not be reached in a few years. But I submit these recommendations to serve as a conscience for the Rules, so that when changes are made, they will be in a consistent direction, in accordance with well defined goals.

Let's throw away the sacred cows that hold back progress!
Let's get seed testing into the 20th Century!


11. Office of Experiment Stations, USDA. 1897. Rules and apparatus for seed testing. Cir. 34. Revised 1904.