A Proposed Severity Index for Seed Handling [1]

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ABSTRACT

Seeds are exposed to various mechanical actions or forces as they pass through handling operations like threshing, separating, conveying, and scarifying. Some actions are relatively severe and cause seed damage. Other actions are relatively gentle and may improve germination of seed species having hard seeds. As a means of minimizing seed damage and improving quality control in seed production, a technique was developed to evaluate severity of handling operations. A formula was devised to relate the severity of mechanical actions to the germination response of seeds handled and permit the calculation of severity index numbers. A comparison of these numbers for a seed lot before and after exposure to handling operations can provide the following information: (1) The severity of a given system; (2) Seed damage, if any, that has occurred; (3) The potential for seed damage that might occur under less favorable conditions; (4) The identity of specific machines or processes that are actual or potential contributors to seed damage. This information is useful in reducing severity of those harvesting or conditioning operations that damage or may damage seed.

Additional index words: **seed harvesting, conditioning, injury, mechanical damage, germination, quality control, hard seed.**

INTRODUCTION

Seeds are subjected to various mechanical actions or forces like impact, abrasion, shear, and compression as they are harvested and conditioned (processed). Such actions may influence the germination capability of seeds and, in some cases, severely injure them. This is particularly true for certain small legume seeds like alfalfa (*Medicago sativa* L.) and clover (*Trifolium* spp.), for vegetable seeds like beans (*Phaseolus vulgaris* L.) and peas (*Pisum sativum* L.), and for oil seeds like soybeans (*Glycine max* L. Merrill) and cotton (*Gossypirm* spp.).

Seed injury causes a substantial loss to the U.S. seed industry. If present damage percentages based on total seed production were reduced by one percentage point, the following amounts of additional viable seed would be obtained annually: 453,000 kg of alfalfa; 384,000 kg of garden beans; 635,000 kg of peas; and 19,195,000 kg of soybeans. (Production figures from U.S. Department of Agriculture, 1980)

Seed damage resulting from mechanical injury can take different forms. Damaged seeds may show external cracks and breaks, or they may appear sound but have internal breakage or other damage. They may germinate and produce abnormal seedlings, or they may be dead. Standard germination tests determine which seeds in a sample germinate normally, abnormally, or not at all. Some seeds fail to germinate because they are dead, while others are restricted from germinating within a prescribed period by natural physiological characteristics of the seeds. A common germination-restricting mechanism for some seed types is a seed coat that is impermeable to water. Seeds with this property are called hard seeds and are generally assumed to be alive and capable of germinating after their seed coats become permeable. Hard seeds and normally germinating seeds are traditionally reported in official germination tests. Upon request, testing laboratories will also report abnormally germinating seeds and dead seeds.

Many investigators have studied seed response to the mechanical actions involved in such handling operations as threshing, separating, conveying, and scarifying. In threshing of bean seeds, there was general agreement that mechanical injury resulting in abnormal seedlings was influenced critically by cylinder speed and seed moisture content (Bainer and Borthwick, 1934; Asgrow, 1949; Toole and Toole, 1960; Dorrell and Adams, 1969). Similar relationships of cylinder speed and seed injury were found for threshing alfalfa and red clover (Bunnelle, Jones and Goss, 1954), for threshing soybeans (Park and Webb, 1958; Moore, 1972), and for threshing crimson clover, (Klein and Harmond, 1966). Seed damage with resultant drop in normal germination was also found related to feed rates for threshing red clover (Bunnelle et al., 1954) and for beans (Asgrow, 1949). In threshing of crimson clover, Park and Webb (1958) noted that hard seed percentages were decreased by aggressive threshing. Franca and Potts (1978) also reported a lowering of hard seed content in threshing of soybeans.

Seed response to mechanical actions associated with the separating or cleaning process has been studied by simulating these actions through various drop or impact techniques. Asgrow (1949) and Atkin (1958) found that the normal germination percentages of bean seeds were reduced sharply by dropping the seeds repeatedly onto a hard surface from heights of 0.61 m and 0.71 m, respectively. Burris (1980) showed that the amount of seed damage caused by dropping soybeans was related to seed moisture content. Similar moisture-damage relationships were found for bean seed by Asgrow (1949) and Perry and Hall (1960). Silbernagel (1973) observed that dropping of bean seeds

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stimulated seedling growth slightly.

The influence of conveying operations on seed germination also has been investigated. Pneumatic conveyors were found to produce seed damage that increased with air velocities when handling alfalfa (Goss and Jones, 1956) and when handling beans (Brandenburg and Harmond, 1964). Asgrow (1949) determined that seed damage in beans was cumulative in repeated passes through an airlift. Andrews (1965) reported similar cumulative damage in repeated passes of seeds through elevators.

The germination response of seeds to mechanical scarification has been the subject of many studies. Scarification is commonly performed on seed of alfalfa, clover, lespedeza (*Lespedeza* spp.), crownvetch (*Coronilla varia* L.) and other hard-seeded legumes to improve germination. Scarifying is accomplished mechanically by abrading or cracking the seed coat to increase permeability. It has been well documented that mechanical scarification can effectively induce some hard seeds to germinate (Battle, 1948; Park and Webb, 1958; McKee, Peiffer, and Mohsenin, 1977). It is also well documented that scarification can be too aggressive and cause seed injury resulting in excessive levels of abnormal germination and/or dead seed (Arnold, 1945; Jones, 1971; Moore, 1972).

In many cases, seed injury from scarification does not appear immediately but shows up later after storage of the seed. Graber (1922), Bret (1952), and others have found that mechanically scarified seeds show greater decreases in normal germination during storage than unscarified seeds. Consequently, this type of scarification is best performed shortly before the seeds are planted.

A different method of reducing hard seed content using radiofrequency electric energy was investigated extensively by Nelson (1976). At optimum exposures, this technique sharply increased normal germination percentages in alfalfa while producing essentially no seed damage. In addition, seed lots treated in this manner showed no deterioration in seed quality after storage periods of 4 years.

Other processes that subject seeds to mechanical actions that may influence germination include drying, debearding, hulling, polishing, treating, blending, and storing.

Mechanical injury to seeds cannot be avoided totally in harvesting and conditioning. However, it is possible to reduce injury by minimizing the severity of operations that expose seeds to potentially damaging forces. The objective of this research study was to develop a technique for evaluating severity and potential for damage in the handling of legume and other seed species having hard seeds. Knowledge of the potential for damage can be used to reduce the severity of a process or specific machine that otherwise may injure seeds and reduce seed value.

DEVELOPMENT AND DISCUSSION OF SEVERITY INDEX

The effect of a mechanical action on seed species having hard seeds can be damaging, beneficial, or neither. A relatively severe action may cause damage, either by killing seeds or causing them to germinate abnormally. A relatively mild action may have no effect or may be beneficial by causing hard seeds to germinate normally. Since the severity of a mechanical action is important, the following formula was devised to rate relative severities of mechanical actions based upon germination response of seeds:

$$\text{Severity Index No.} = \frac{1 + (AG + DS)}{1 + HS} \quad \text{- - - - - - - (1)}$$

Where: AG = abnormally germinating seeds, percentage by number
DS = dead seeds, percentage by number
HS = hard seeds, percentage by number
[As determined in standard tests for seed germination (International Seed Testing Association, 1976)]

A term for normal germination of seeds is not included in the formula because any change in this measure caused by a mechanical action will be reflected in revised values for the abnormal, dead, or hard seed terms. The arbitrary figure of 1 appears in both numerator and denominator to provide finite numbers and a mathematically rational condition when the hard seed content or abnormal germination plus dead seed percentage is zero.

When applied to seed lots before and after handling, the formula can sense and measure actions that damage seeds (change the numerator) or cause hard seeds to germinate (change the denominator). The initial index number for a seed lot will change when the action produces any of the following events: (1) Initially hard seeds germinate normally, germinate abnormally, or are killed; (2) Initially normally germinating seeds germinate abnormally or are killed. These events are shown schematically in Figure 1 along with another event where initially abnormally germinating seeds are killed (no change in index number). Some seeds of each germination category shown in Figure 1 may be present originally in a given lot of seed. Exposure to a mechanical action can shift seeds from one category to another in the directions indicated.

Considering all of the described possible germination responses, the numerator of the formula either increases or stays the same, and the denominator either decreases or stays the same. As a result, the calculated index number must either increase or stay the same for seeds subjected to any mechanical action.

As severities of actions increase, the first change (increase) in index number usually results from a decrease in hard seed content. This seed response is the basis for the practice of scarification. Hard seeds are encouraged to germinate because the mechanical action tends to increase permeability of the seed coat. Greater levels of severity tend to eliminate more hard seeds but also may cause seed damage by increasing abnormal germination and/or dead seed percentages. These germination responses, which may be seen in the flow diagram of Figure 1, will result in higher index numbers. For purposes of this discussion, damage may be considered an extreme form of severity.

Some severity is desirable in harvesting and conditioning seed lots that contain hard seeds. Ideally, the mechanical actions involved should be severe enough to reduce hard seeds, but not severe enough to damage seeds. This level of severity will cause an increase in normal germination. As

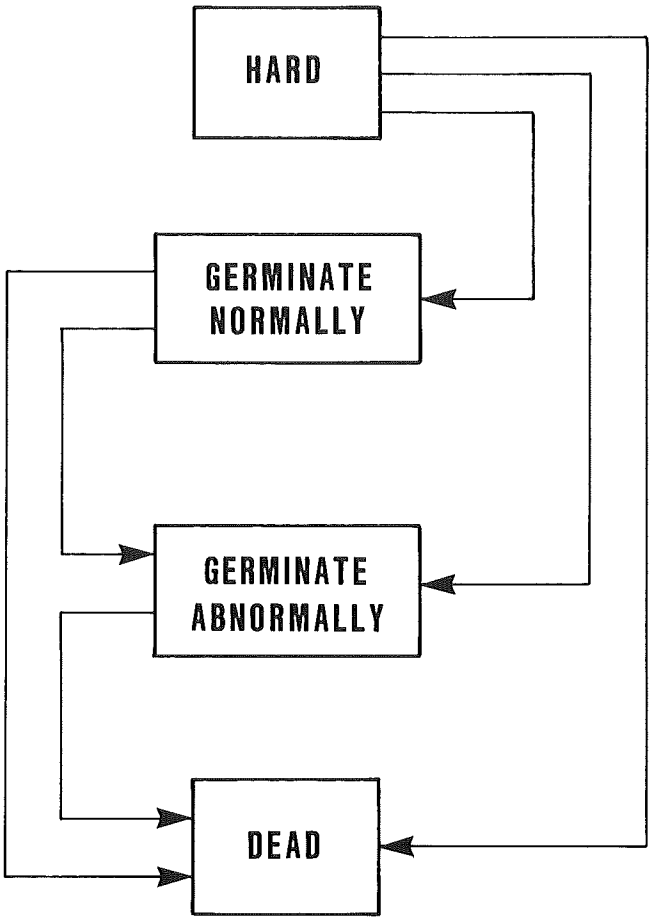


Fig. 1. Possible changes in germination categories of seeds subjected to a mechanical action.

reflected in the formula, there will be a decrease in denominator but no increase in numerator, resulting in an increased severity index number but no damage.

A different type of seed index that relates damage vulnerability to seed characteristics was reported by Potts (1972). In this case, a number denoting seed structure was multiplied by a number denoting chemical composition to obtain an index value called the damage susceptibility index (DSI). Considering seed properties only, DSI values can indicate the need for greater care in handling certain damage-sensitive seed types. In contrast to the DSI, the severity index developed here is concerned with a given seed lot and its germination response to the mechanical actions of a given seed handling operation.

An equivalent form of formula (1) can be stated to permit computation of severity index numbers using the terms normal germination and hard seed that are traditionally reported by seed testing laboratories. Since the four categories of germination as indicated in Figure 1 must total 100 percent in standard tests,

$$100 = NG + HS + AG + DS$$

$$(AG + DS) = 100 - (NG + HS) \text{ - - - - - - - - -(2)}$$

Substituting for (AG + DS) in (1):

$$\text{Severity Index No.} = \frac{1 + 100 - (NG + HS)}{1 + HS}$$

$$= \frac{101 - (NG + HS)}{1 + HS} \text{ - - - - - -(3)}$$

Where: NG = normally germinating seeds, percentage by number
HS = hard seeds, percentage by number
AG = abnormally germinating seeds, percentage by number
DS = dead seeds, percentage by number
(As determined in standard tests for seed germination)

The severity index number is useful in determining the degree of severity in a harvesting or conditioning operation. A relatively large increase in index number due to a handling operation indicates a substantial degree of severity in the operation. And, the higher the level of severity, the greater the chance for seed damage. In a practical application, the severity index formula was used to rate severity and potential for damage in a pneumatic conveying system transporting crimson clover. The system was operated at different levels of aggressiveness produced by varying air velocities, conveying rates, and number of passes. Results are presented in Figure 2. The severity index curve clearly

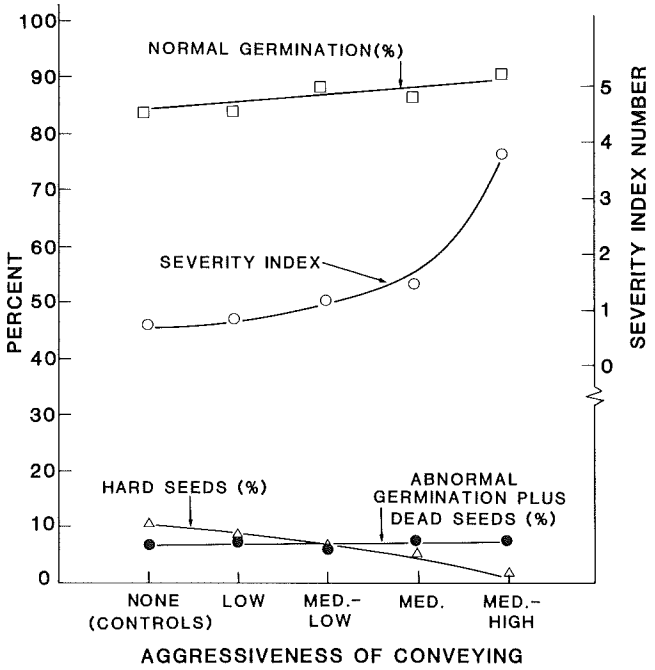


Fig. 2. Severity index numbers and seed germinations in pneumatic conveying of crimson clover (*T. incarnatum.*) Plotted points are averages of two or more determinations.

shows that the potential for damage increased as aggressiveness increased, even though no change was apparent in actual damage (abnormal germination plus dead seeds) as measured by standard germination tests.

Studies referred to earlier showed that damage varies with seed moisture, rate of handling, number of passes through a machine, and other factors. Since the point at which damage first occurs can change with these variables, it is a sensible precaution to closely monitor and perhaps reduce severity of a handling operation that causes a large increase in index number.

Handling severities can be reduced either by changing operating techniques in an existing system or by changing the system. The potential for seed damage can be lessened by conditioning seeds at their optimum moisture content for minimum damage, lowering the flow rate, and reducing number of passes. System changes that tend to decrease damage potential include eliminating some conditioning machines, reducing height or impact of seed drops, decreasing discharge velocities of bucket elevators, and decreasing air velocities in pneumatic conveyors.

The severity index number also can be used to compare seed handling operations according to degree of severity. On this basis, relative severity ratings for handling operations can be determined either for a total system or for components of a system. For example, consider two alternative conditioning systems that show no seed damage for the same seed lot as determined by usual measures. Although both systems appear satisfactory, severity index ratings may reveal that one system is less severe than the other. In this case, the system showing lower severity would be preferable since it is less likely to produce seed damage under more adverse operating conditions. Similarly, components of a particular conditioning system can be numerically rated and compared individually to identify specific machines or processes that are potential contributors to seed damage. Once identified, the machine or process may then be modified to reduce its severity.

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