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Proceedings
1984 SHORT COURSE
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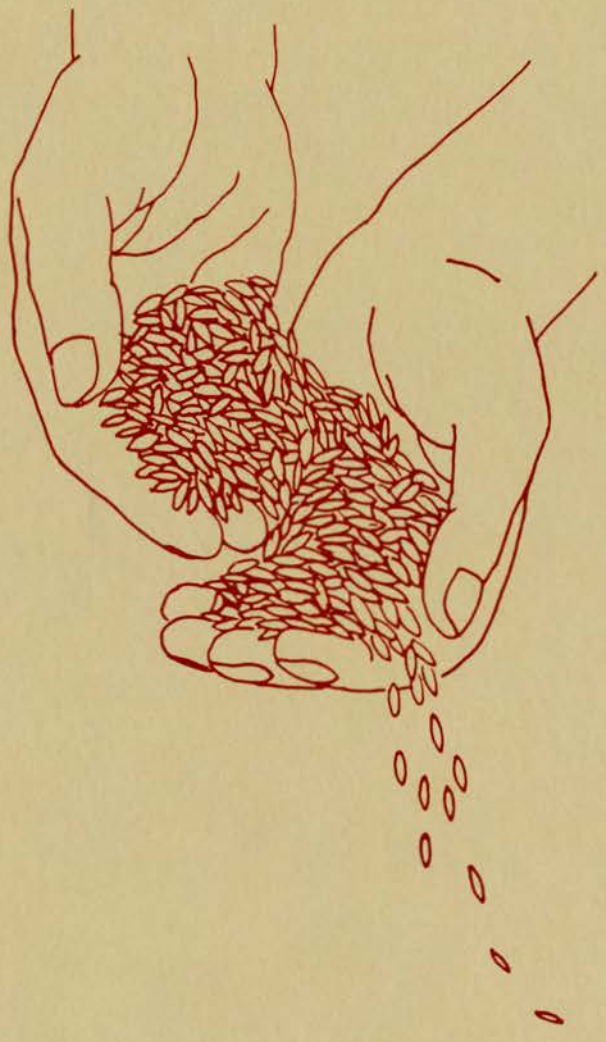
SEEDSMEN



Volume 26

April 9-11, 1984

SEED TECHNOLOGY LABORATORY

MISSISSIPPI STATE **MISSISSIPPI**

Sponsored By The Mississippi Seedmen's Association

PROCEEDINGS (VOLUME 26)

THIRTY-SECOND SHORT COURSE FOR SEEDSMEN

APRIL 9-11, 1984

SEED TECHNOLOGY LABORATORY

MISSISSIPPI STATE UNIVERSITY

MISSISSIPPI STATE, MISSISSIPPI 39762

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Seed Trade News
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Seed World Publications
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SEEDS - DEVELOPMENT, STRUCTURE AND FUNCTION

Howard C. Potts[1]

You depend upon seeds for your livelihood but what do you know about this amazing product of nature? What is a seed - this thing on which we all depend so heavily?

As you know, we plant seeds, grow seeds, harvest seeds, dry seeds, clean seeds, grade seeds, package seeds, store seeds, test seeds, and hopefully sell seeds - yet most of us don't have the capability to set down and outline, even in simple botanical terms, the basic processes and structures involved in the complete life cycle of a seed from flower formation through germination. Let's face it, seeds are our baby. Why this taboo on the sex life, structure and function of seeds? We can no longer blame Queen Victoria for our ignorance about sexual reproduction. Surely every professional should know and understand the produce from which he earns his living. How professional are you or how professional am I in this respect?

Somewhere in your educational career you have been told about the birds, the seeds and the flowers. The major portion of my discussion will deal with "the flowers."

There is a point in the life cycle of every plant when the balance of physiological processes shifts from vegetative growth to the development of reproductive structures. It is at this point that seed development really begins. For the remaining period of the growth cycle, the plant's entire physiological being is geared to development of the reproductive structure which we call a seed.

Generally we do not concern ourselves with this shift in growth emphasis until we observe its visible expression in the form of flowers, panicles, ear shoots, etc. But morphological studies indicate that by the time these outward expressions of reproduction are observed the plant has used approximately one half of the total time that it will devote to reproduction. Time wise, then, we really get interested in this ballgame only after the first 4 1/2 innings have already been played. Then we jump and yell "send me in coach" or we decide to call the game because of a dry field.

Fortunately for us, plants are not as "pessimistic" as people. Except in the most unusual circumstance, every plant will produce at

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[1]Professor, Seed Technology Laboratory, MSU.

least one good seed or die trying. This basic drive for reproduction of the species is apparently much stronger in plants than in animals.

As seedsmen we must always remember that the plant does not produce seed for our use but to maintain itself. Have you observed the fact that plants produce only the number of seed that can be completely developed rather than producing a larger number of partially developed seed? Maybe people are not as "smart" as plants!

Let us now turn our attention to the sequence of events that naturally occur in the development of the seed giving consideration to the structure and function of the developed seed.

All seed producing plants have flowers! Some are pretty, some ugly, some small, some large - they come in an endless variety of colors, sizes, and shapes. There are "boy" flowers and "girl" flowers but most flowers are hermophidites - that is, the flower has both the male and female reproductive organs in the same flower. Some weird ancient botanist designated these as perfect flowers. Now, let's look at a typical flower and delve into its sex life.

Plate 1 is a cut-away drawing of a typical flower and is labeled with the scientific names of the various parts of a complete flower. Technically, all of the sepals together are called the calyx and all the petals together are called the corolla. These structures have no direct role in reproduction.

Of primary concern are the stamen, which is the male flower, and the pistil, which is the female flower. You will note that the stamen has two principal structures, the filament and the anther. The anther is the "business end" of the stamen and the filament the stalk which supports the anther. In each species it positions the anther to allow it to most effectively perform its role of production and distribution of the male sex cells which we call pollen. When the anther splits, releasing the pollen, its role is completed. In most species there are several hundred times as many pollen grains produced as there are female flowers needing fertilization. Thus, the male flower says "here it is girls" and the "girls" may or may not be interested.

The pistil consists of three basic parts: the stigma, style and the ovary, which may contain one or many ovules. The stigma may be knobby, featherlike, or long and slender. Regardless of the shape it is normally covered with a sticky stigmatic fluid which acts both as an adhesive to hold the pollen grain and to supply moisture for the pollen grain's germination. When pollen of one species lands on the stigma of another, it normally will not germinate, although in closely related species it may.

The style performs two functions. First, it is responsible for the physical placement of the stigmatic surface in a predetermined position which will increase the probability of the desired pollen

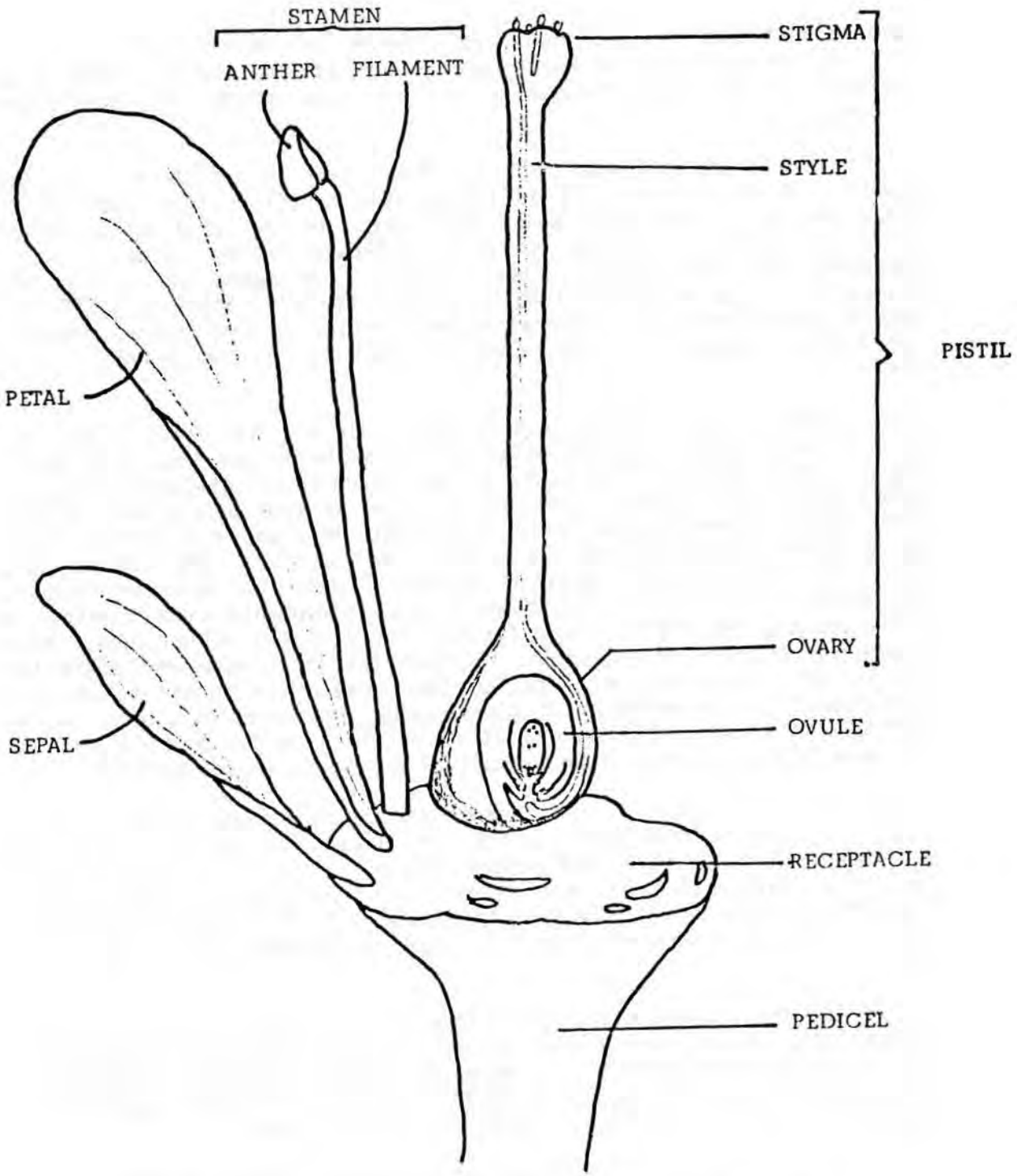


PLATE 1 CUTAWAY VIEW OF TYPICAL PERFECT FLOWER

landing on the stigma. Second, its internal cellular structure is such that it protects and enhances the growth of the pollen tubes from desirable pollen and discourages pollen tube growth of undesirable species.

The ovary is that part of the flower in which we have the greatest interest because it is inside this structure that the seed or seeds develop. The organ which gives rise to the seed is called an ovule and there may from one to several thousand ovules inside an ovary, depending upon the species. Corn, sorghum, lespedeza and zinnias are examples of ovaries containing a single ovule. Soybeans, alfalfa, watermelon and okra have several to many ovules in each ovary. Regardless of the number of ovules, each one conducts its own private little affair.

Let's take a close look at the ovule and its parts (Plate 2). Here we see a cross section of a typical ovule inside the ovary wall. The principle parts of the ovule are the funiculus, integuments, micropyle and the embryo sac. The funiculus, or as some people call it the ovule stalk, connects the ovule to the mother plant functioning similarly to the umbilical cord in animals and rockets. The integuments, there are normally two, serve as delicate fingers to hold and support the embryo sac. At the point where the integuments come together a small opening remains to allow for the entry of the pollen tube. This opening is called the micropyle. Between the inner integuments and the embryo sac a layer of cells called the nucellus is formed to aid the nourishment of the embryo. In some species the nucellus gives rise to embryos and subsequently seed which do not require the participation of the male. Such an event is an example of a process called apomixis.

The embryo sac is the "heart" of the ovule and the location of female egg cell which when fertilized gives rise to the seed. In addition to the egg cell most mature embryo sacs contain 7 other cells; the three anitpodal cells are relatively unimportant as are the two synergid cells which are located on either side of the egg cell. The 2 polar nuclei are very important in seed development as we shall see later.

In most species the development of both the male and female reproductive organs are syncronized and they reach maturity together. If they do not mature together I believe you can readily recognize that the more advanced sex will go "looking for a partner." Plants where this normally occurs we refer to as being cross pollinated.

There are several other mechanisms which lead to cross pollination. The mechanics of pollination and fertilization are simple. For each ovule (egg cell and polar nuclei) to be fertilized a pollen grain of the same species must land on the stigmatic surface. This is pollination. After the pollen grain germinates (Plate 3) the two sperm cells remain near the growing point of the pollen tube. When the pollen tube passes through the micropyle reaching the embryo sac it ruptures

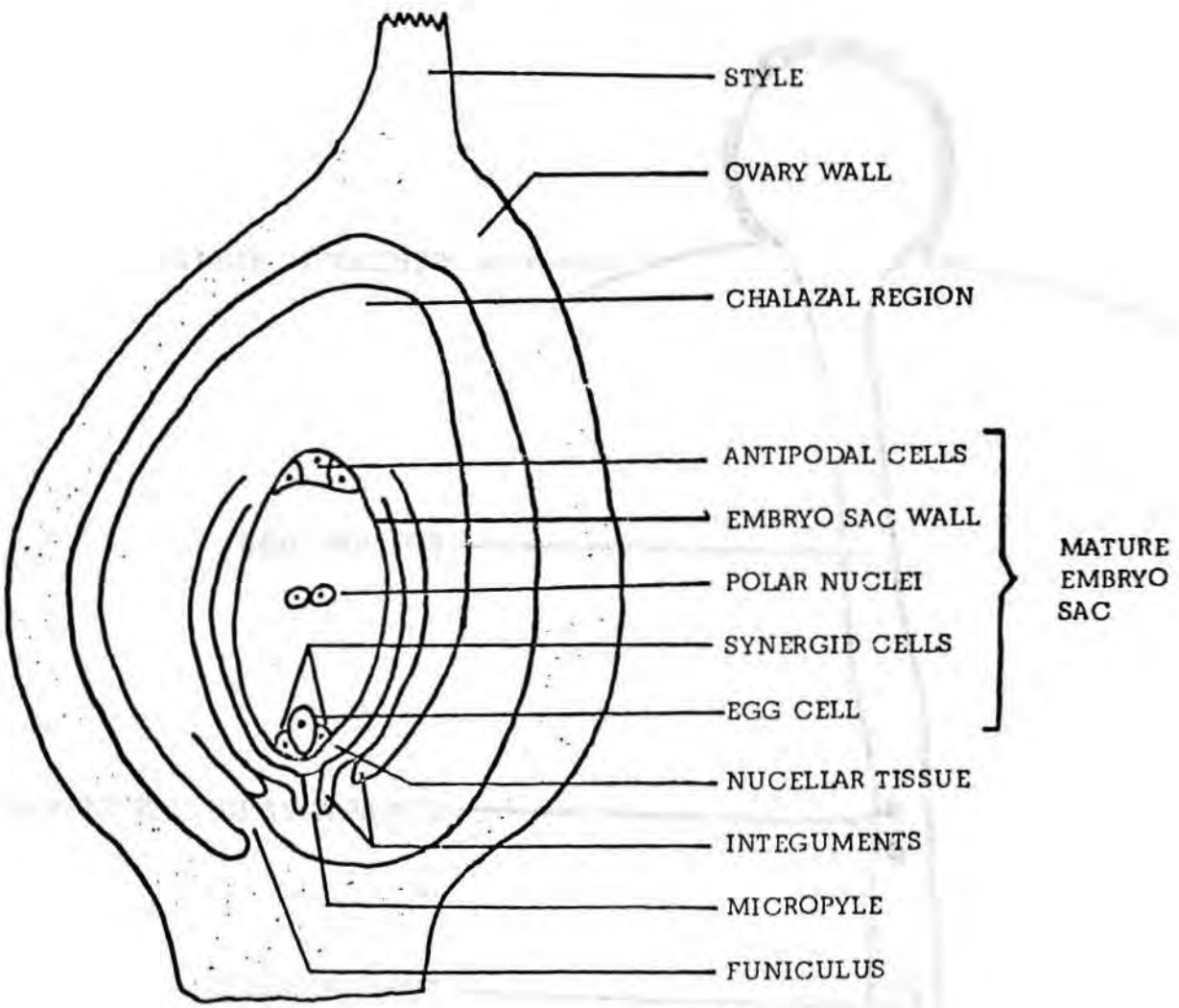


PLATE 2 CROSS SECTION OF OVARY AND OVULE

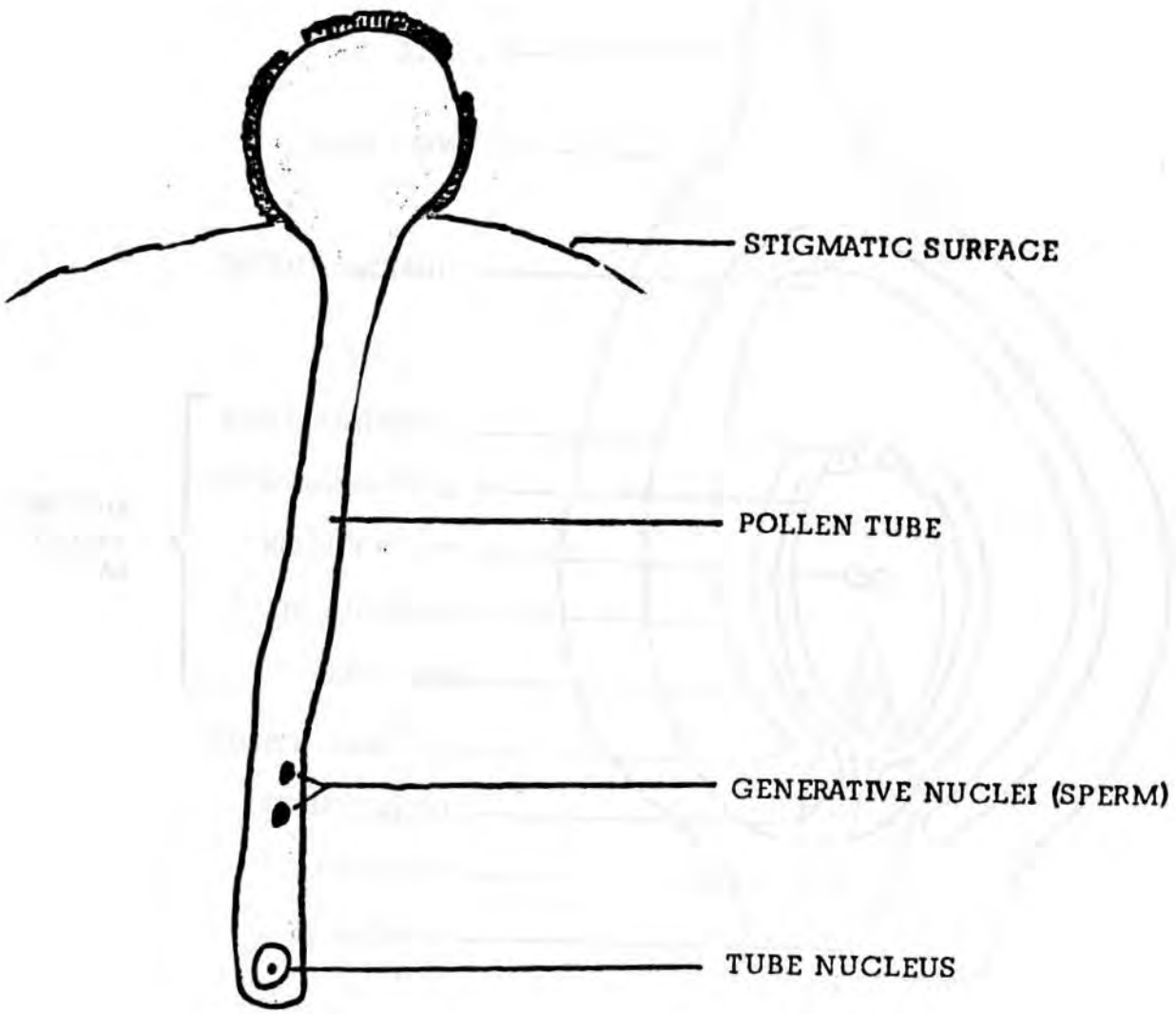


PLATE 3 GERMINATED POLLEN GRAIN

releasing the two sperm into the embryo sac. One sperm units with the two polar nuclei and the other with the egg. This process is called double fertilization and is unique to the plant world.

The union of a sperm and the egg forms a cell called the zygote. It is this cell which starts the new generation and gives rise to the embryo. The other union forms the endosperm which we often refer to as part of the embryo, though technically it is not. The primary function of the endosperm is to provide nourishment for the embryo as it develops. The five antipodal and synergid cells degenerate shortly after fertilization.

The newly formed cells start division almost immediately with the endosperm initially dividing the more rapidly of the two. With the first division of the zygote, which is always on a transverse plane, the polarity of the new plant is established. That is the new cell formed nearest the micropyle will give rise to the roots and other associated parts. The other new cell will give rise to the above ground; stem, leaves and eventually flowers. You can turn the plant any way you want but it won't change this fact.

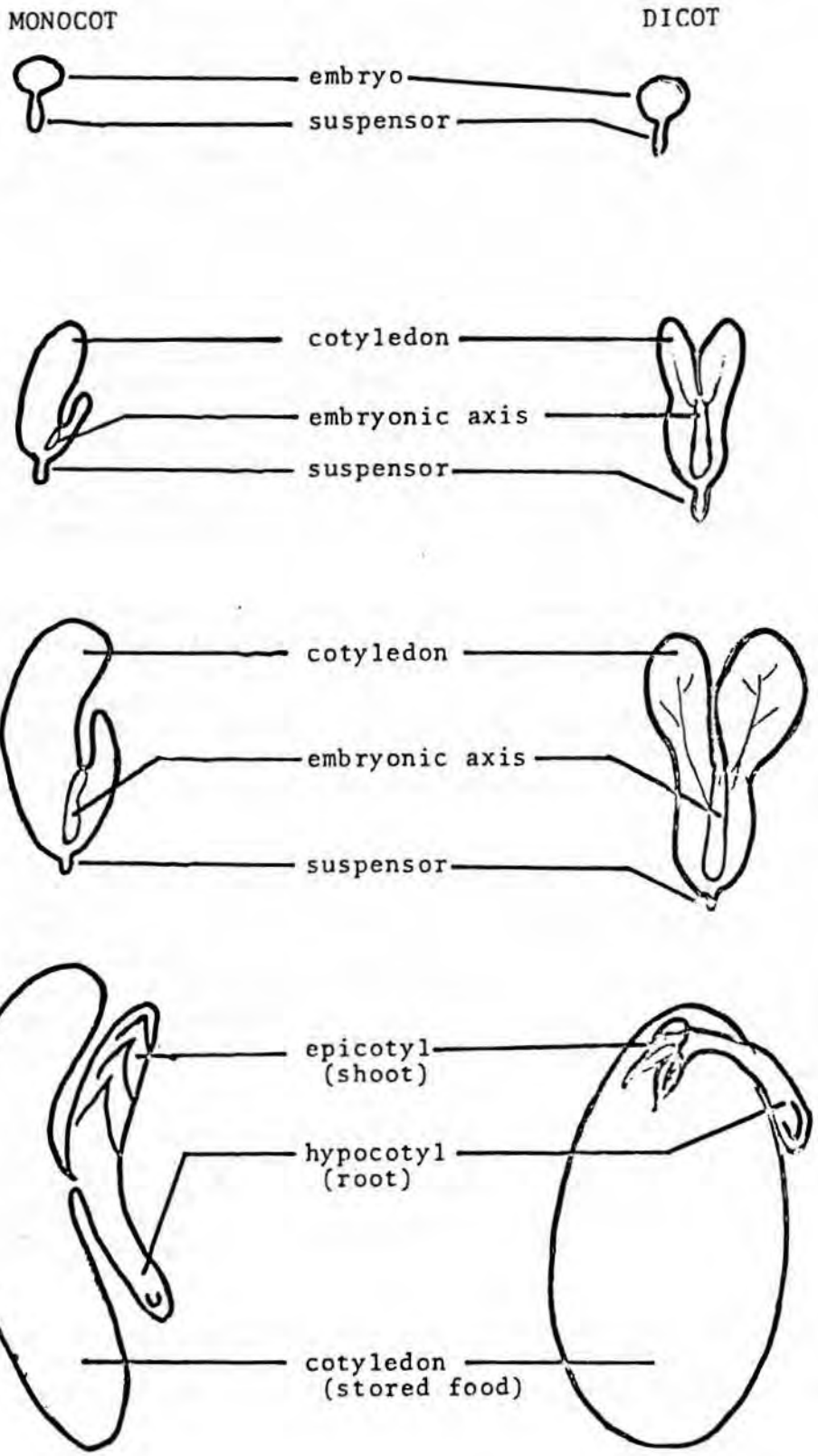
For the next few hours, days, or weeks the embryo and endosperm cells divide rapidly with the plant's entire system being devoted to the nourishment and development of the embryo. If the soil cannot provide the chemical compounds required for the seeds' development some compounds are transferred form other parts of the plant to nourish the seed. Thus, we often see the familiar symptoms of nutrient deficiency accentuated as the seeds develop but it's too late to add chemical fertilizers.

A few days after fertilization of the egg cell we can see the first signs of distinction between the dicotylodonous (seeds having two cotyledons) and monocolyledonous (seeds have one cotyledon) species. Up to this point essentially the entire developmental process is the same. A brief study of Plate 4 will reveal that the presence or absence of the second cotyledon is the primary difference in embryo development from now until maturity. Otherwise, the essential structures of the developing embryos are the same.

You will notice that at maturity seeds of both the monocot and the dicot have (a) an embryonic axis, which terminates at one end with the embryonic root and at the other with an embryonic shoot, (b) a source of stored food, in the cotyledon(s) and in some species the endosperm or nucellus and (c) a protective covering, called the testa or seed coat.

When using the term maturity I believe that some of you might think of a golden field of grain. If you do, you are not thinking with me. A seed is mature when it reaches the stage of maximum dry weight.

PLATE 4 4 STAGES OF EMBRYO DEVELOPMENT



It is at this strategic stage in the development of a seed which signifies the attainment of maximum potentiality for performance, in most economically important species.

Attaining maturity may be regarded as a positive process which includes: increase in seed size, accumulation of dry weight, development of the essential structures, a loss of moisture, and an increase in viability and vigor. Almost immediately following maturity, the seed enters a negative phase which is characterized by a decline in viability and vigor caused by respiration, high temperature, high humidity, mechanical injury and time. This phase is terminated by the death of a seed. This can be visualized by observing Plate 5.

Thus, the waving field of golden grain does not represent a field of mature seeds rather the field is a terribly exposed storage place for seeds which have already entered the negative phase we call deterioration. Therefore, our concept of maturity is very important when considering harvesting, drying, storage, an subsequent field performance of the seeds.

Let us now consider some aspects and characteristics of mature seeds which are determined by the developmental processes already discussed. As I indicated a seed consists of an embryonic axis, stored food and the testa or seed coat. To equate the botanical terms used in discussing the flower and seed development into terms of the seed, refer to Plate 6. The seed coat, hilum and micropyle can be observed rather easily on most seeds. A simple cross section follows identification of the other essential organs of a seed (Plate 7).

Most seeds have one or more structural weaknesses which are an unending source of problems to us as seedsmen. It seems that God, in his infinite wisdom, overlooked the brutality to which man would subject seeds of the various species. On the other hand, maybe we should change some of our methods to better align them to the seeds with which we deal.

Consider the seed coat which, when undamaged, is a better protectant than any seed treatment that we may add. In the coconut or brazil nut the seed-coat is hard and offers excellent protection to the delicate embryo but most seeds are not so fortunate. Rather they are protected by a thin shell like an egg which, in our mechanical age, is easily broken by dropping or at best a slightly more severe shock. We are fortunate that many of the seeds we use are either so small, light, or are protected by additional coverings as in the case of many of the grasses, and, therefore, escape our attempts to kill them.

In many species the embryonic axis is exposed (Plate 8) and like our nose catches the brunt of a headlong impact. But unlike our noses the embryonic axis once broken cannot be taped over and left to heal. The removal of the seed coat from many seeds will reveal the axis' exposed position.

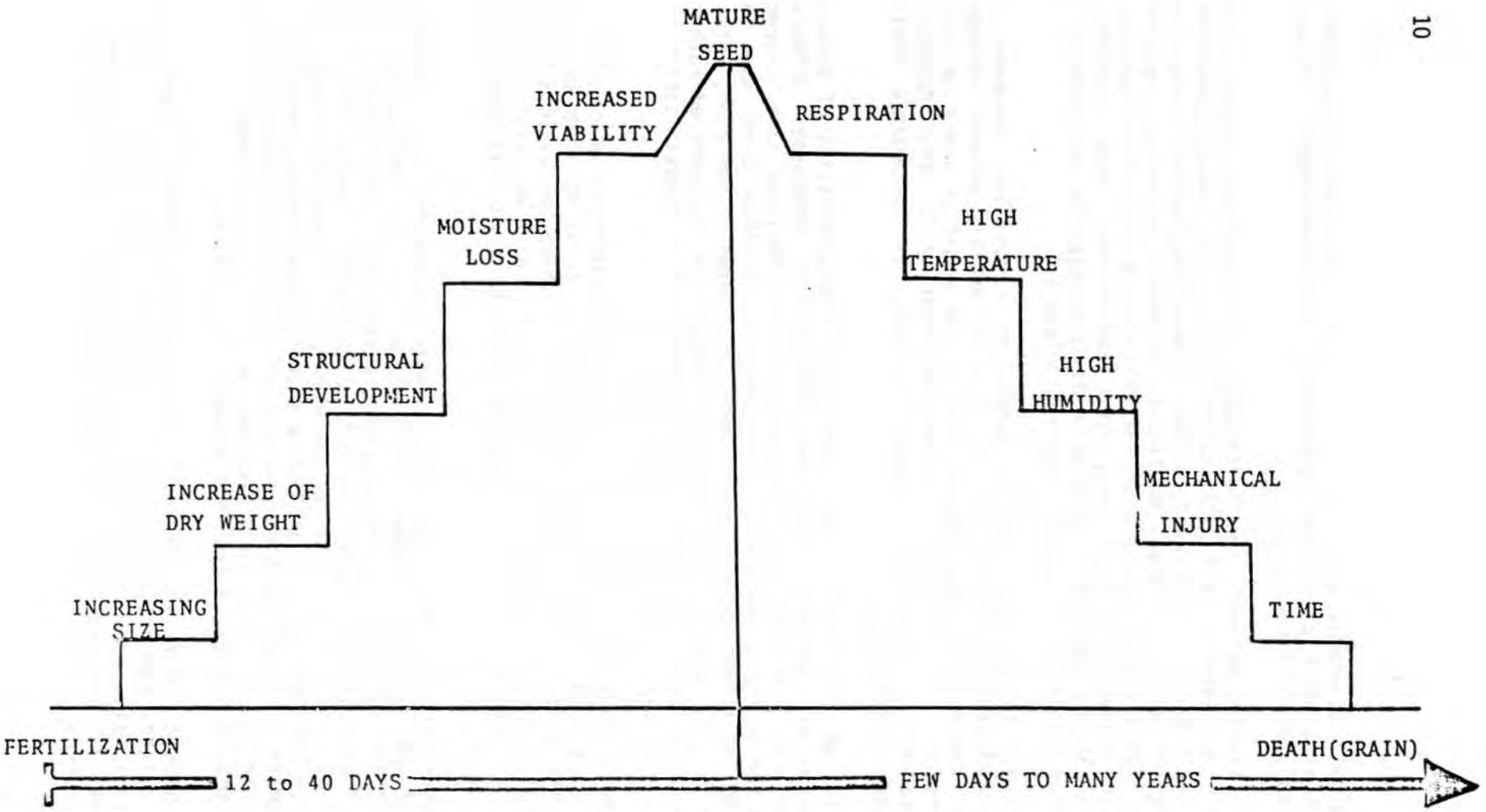
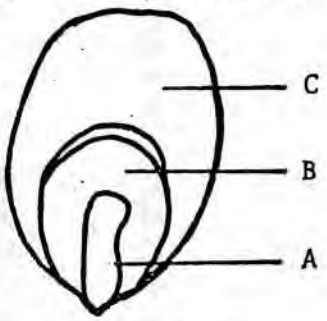


PLATE 5 THE RISE AND FALL OF A SEED'S CAPABILITIES

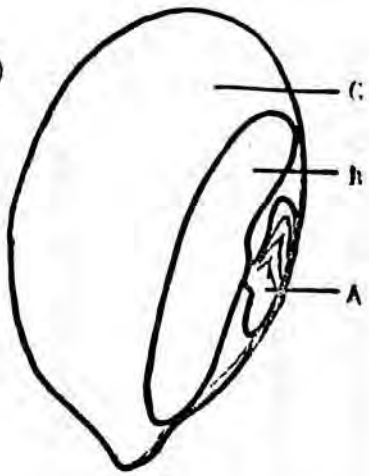
AT FLOWERING	AT MATURITY
OVARY	FRUIT (SOMETIMES COMPOSED OF MORE THAN ONE OVARY PLUS ADDITIONAL TISSUES)
OVULE	SEED (SOMETIMES COALESCES WITH FRUIT)
INTEGUMENTS	TESTA (SEED COAT)
NUCELLUS	PERSIPERM (USUALLY ABSENT OR REDUCED)
2 POLAR NUCLEI + SPERM NUCLEUS	ENDOSPERM (TRIPLOID-3N)
EGG NUCLEUS + SPERM NUCLEUS-------ZYGOTE	EMBRYO (DIPLOID-2N)
MICROPYLE	MICROPYLE
FUNICULUS	HILUM (SCAR LEFT BY BREAKING OF THE FUNICULUS)

PLATE 6 RELATIONSHIP OF FLOWER TO MATURE REPRODUCTIVE STRUCTURES

GRAMINEAE (grass family)



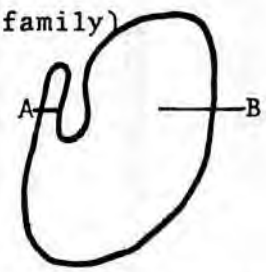
Sorghum spp



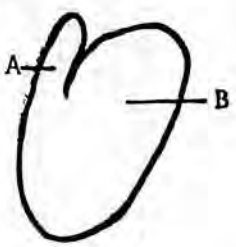
Panicum spp

Leguminosae (legume family)

Pisum spp

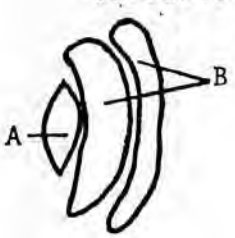


Melilotus spp



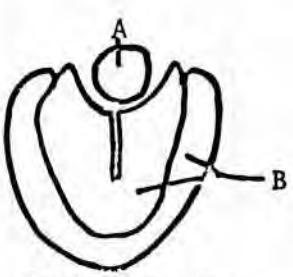
Trifolium spp

Crucifereae (mustard family)



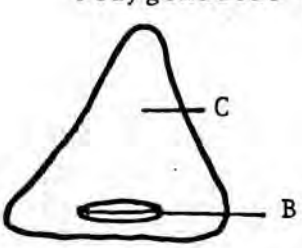
Lepedium spp

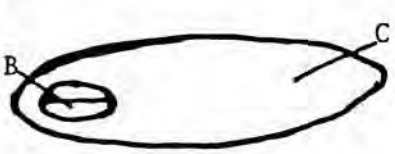
Brassica spp



Raphanus spp

Polygonaceae (buckwheat family)





A = radicle or embryonic axi

E = cotyledon

C = endosperm

PLATE 7 STRUCTURAL RELATIONSHIPS OF VARIOUS SEEDS

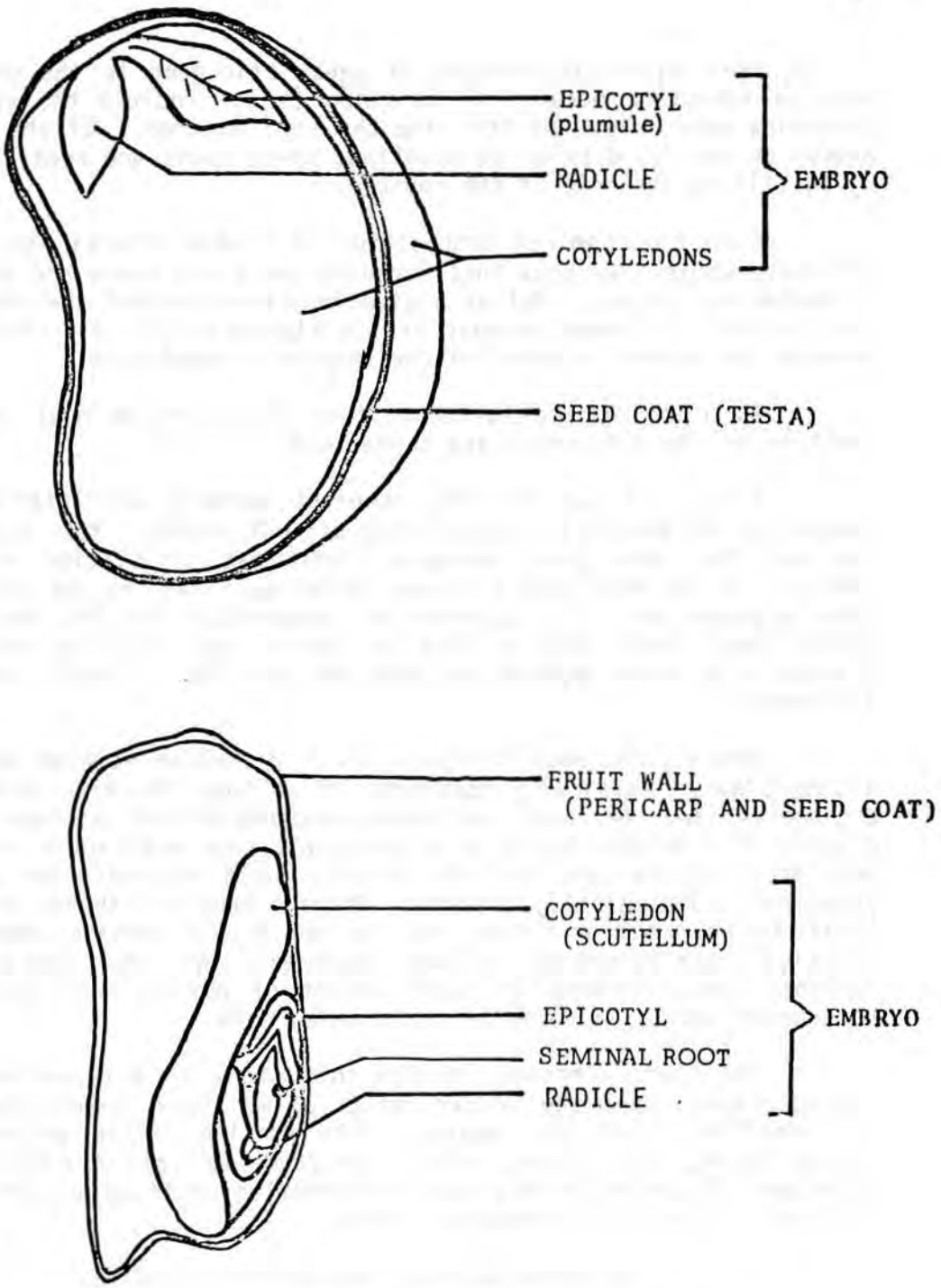


PLATE 8 STRUCTURE OF TYPICAL DICOT AND MONOCOT SEEDS

Here again the embryos of seeds belonging to the grass family have an advantage because in addition to the radicle the seminal root primorida were formed by the time the seed matured. If the radicle is broken or destroyed prior to planting, these roots are ready and capable of fulfilling the role of the radicle.

Even the chemical composition of a seed affects its ability to withstand abuse. We know that soybeans and field beans are very subject to mechanical injury. But at a given moisture content the field bean is more subject to damage because of its high starch to oil content simply because the starch is more brittle than oily substances.

As a logical conclusion to this discussion we must consider the function of the seed which are three fold:

First, it carries the inherent genetic characteristics from generation to generation essentially without change. Yes, I am aware of the fact that some plant breeders claim that irradiation of seeds has resulted in the development of new varieties. Yet, no one has presented data to prove that this exposure was responsible for the new varieties; rather they state that a line or strain was selected from a field planted with seeds exposed to ionizing radiation. There is a distinct difference.

Second, the seed functions as an effective storage system for a living plant. Physically speaking, if we took the most scientifically engineered and equipped refrigerated-dehumidified storage room and dropped it from the top of a building you know what would happen. Yet, most seeds of the same specific gravity would be unaffected by the same treatment. Biologically speaking, leave a head of cabbage on a kitchen table for a month and then try to use it. A cabbage seed would be relatively unaffected by the same treatment. No other container or its contents can withstand an equal amount of physical and environmental punishment and still perform its intended role.

The third function, brings this story to a close and this, is reproduction. When the proper ratios of moisture, temperature, oxygen and sometimes light are reached, this amazing little package of life spring forth, root first, into a structure we call a seedling. Then once again the miracle of a seed is forgotten until we see the beauty of a flower or the golden field of grain.

Now as we continue through this meeting,
then go our separate ways:
I ask that each of you remember not;
my simple words of praise;
But rather, behold the seed I have,
and the amazing role it plays.

SEED COVERINGS - AN APPRECIATION[1]

James C. Delouche[2]

Coverings are one of the three general structural components of a seed and contribute in crucial ways to its propagative function. The origins and basic designs of the coverings on seed are limited, but they - the coverings - are almost infinitely variable in detail. Some coverings are smooth as polished wood, while others are intricately - even exquisitely - ornamented; some are drab, others flamboyantly colorful; some are delicate like fine tissue, others are hard as stone and tougher than leather; some are affixed with various projections and appendages, others are essentially featureless; most are aesthetically pleasing, but some are exasperating, especially to seed producers and conditioners. The old adage, "you can tell a book by its cover" applies. Seeds are mostly recognized and/or identified by their characteristic coverings.

The Source

The origins of seed coverings are few. The basic covering is the seed coat which develops from structures called integuments that enclose or surround the ovule in seed plants. The ovule, of course, is the sexual structure that, after fertilization, develops into the seed. (A seed is a mature ovule!). Gymnosperm (e.g., conifer) seed are covered only by the seed coat because they are "naked" and not borne in a fruit as is the case of the Angiosperms - the plant group to which most of our crop species belong.

Diversity in Form

Seed coverings are most diverse and complex in the Angiosperms because in addition to the "true" seed coat, they - the coverings - can include all or part of the fruit covering and various structures surrounding the fruit. The extent to which structures exterior to the seed coat, i.e., the "true" seed, are part of the seed coverings is determined by the nature of the "unit of dispersal." The unit of dispersal ranges from the true seed to multiple seeded fruits surrounded by bracts and appendages. The unit of dispersal for soybeans is the seed which is

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released at pod (fruit) dehiscence and covered only by a rather thin seed coat. The dispersal unit for cocklebur, on the other hand, is a formidable structure that contains two one-seeded fruits. In both cases - soybean and cocklebur - the structures exterior to the reserve storage tissue and embryo/embryonic "axis" are coverings and influence the functioning of the "seed" as the propagative unit.

Adaptative Value

There are many examples of adaptations of seed coverings to facilitate seed dispersal: the fibers of the cotton seed; the pappus or parachute of dandelions; the barbs of the cocklebur. Since seed dispersal is important for the survival of the species, the appendages and other projections from the seed coverings that aid dispersal play an important role in natural propagation. These accessories and appendages, however, are a nuisance in crop propagation and, as mentioned above, exasperating to seed producers and conditioners.

Problems in Conditioning

Appendages of seed coverings such as spines, awns, long hairs and fibers, coarse pubescence, wings and persistent "extra" coverings, such as hulls, add useless bulk to and reduce the flowability of seeds - to about zero in some cases. Seed that have poor flowability are difficult to impossible to handle, clean and package efficiently. Special and additional operations are required to "precondition" them so that they can be adequately conditioned. Consider some of the operations that are involved in changing the physical properties of seed coverings to reduce useless bulk, improve flowability, singulate the seed, and facilitate mechanical planting.

Defuzzing - reduction of the pubescence of tomato seed to singulate them and improve flowability.

Defringing - removal of the "fringes" along the "seams" of carrot seed to singulate and improve flowability.

Dewinging - removal of the "wings" of pine seed and other kinds of tree seed to reduce bulk and increase flowability.

Debearding - (also deawning) removal of awns and other projections from seed to increase bulk density, flowability and plantability.

Delinting - primarily applied to cotton; removal of the residual short linters from cotton seed mechanically or chemically to increase bulk density and improve flowability and plantability.

Clipping - removal or "clipping" of the loose ends of the hulls of oats to improve bulk density, flowability and plantability.

Hulling - removal of the hulls or pod from seed for a variety of purposes: to increase density, flowability and plantability; to improve germinability (bermudagrass); to change physical properties of the seed so that weed seeds can be separated (lespedeza).

Breaking-up - break-up of unthreshed pods (flax bolls), spikelets, and so on, to facilitate cleaning and reduce seed loss.

The processes mentioned are done purposely with special equipment such as huller-scarifiers, modified hammer-mills, popcorn polishers, and debearders for the various reasons mentioned, e.g., to increase density. Sometimes similar modifications in seed coverings that are effected more or less incidently to other operations such as harvesting contribute to rather than relieve conditioning problems. Cockleburs, for example, are harvested and ginned along with the seed cotton. The burs are altered during ginning which makes them similar in size to cotton seed and difficult to remove. Johnsongrass seed hulled during harvesting and handling are much more difficult to separate from certain kinds of crop seed than unhulled Johnsongrass seed.

Coverings and appendages of seed reach their zenith as exasperating nuisances in some of the range and tropical grass species. The threshed seed can have a consistency more nearly like hay than seed and useless bulk might constitute 90% or more of the volume and 50% or more of the weight of the mass. But, range and tropical grass seed producers are ingenuous and persistent and do quite remarkable work producing and supplying seed of some of the really monster species.

Functional Roles of Coverings

The role of seed coverings in seed dispersal is one of their most evident functions. Another related and, perhaps, even more evident role or function of the seed coverings is containment.

Containment

The embryonic axis and nutritive tissue - the essential elements of the seed - are enclosed and contained by the seed coverings, thus, maintaining the spatial relationships of the two elements during the events that culminate in germination and even later.

The containment role of seed coverings cannot really be separated from the protective and regulatory roles or functions, which are most crucial in terms of germinative success. The seed coverings not only contain the embryonic axis and nutritive tissue, they also protect these vital, often fragile, elements.

Protection

The protective role of the seed coverings has two aspects: mechanical protection against physical forces; and barrier protection against the entry of microorganisms. The mechanical aspect of the protective role has become increasingly important - and appreciated - with increasing levels of mechanization of harvesting, handling and conditioning operations. In the natural order of things, that is, before the intervention of man in the life cycle of plants, the mechanical properties of the seed coverings were undoubtedly of lesser importance than they are now. Properties of the coverings that resisted digestive processes and permitted the seed to pass through animals functionally unimpaired were of greater importance than their sheer mechanical strength.

Effects of Man's Intervention: Since the intervention of man, however, the requirements of the human food grinding and digestive systems have caused conscious and unconscious selection of food grain types with more digestible, less mechanically strong seed coverings, or at least with more easily removed coverings. These preferences continue. Just a few years ago a breeder pointed out that the soybean seed coat didn't really contribute anything of value to the "product", and that if it could be reduced to one half of the portion of the seed it presently constitutes, the "difference" in terms of base chemicals and energy might show up in usable products - oil or protein. Little thought was apparently given to the problems that would arise in maintenance of soybean seed quality if the varieties were developed with thinner, even more fragile seed coverings.

Mechanical Damage: Mechanization of harvest, handling, and conditioning operations subjects seeds to physical forces that can and do exceed the mechanical resistance of the seed coverings and the seed as a whole to slowly applied static loading (crushing), impacts, abrasions, and various types of cutting and shearing actions. The failure of the seed coverings to protect the embryonic axis and nutritive tissue from physical damage affects the germination capacity of the seed. The degree to which germinative capacity is affected is determined by the severity and location of the damage. Gross damage manifested as splits, cross broken, decoated, and crushed seed immediately and irrevocably destroys the germinative capacity of seed. Lesser degrees of damage generally have lesser consequences, although rather slight damage to a critical site of the embryonic axis can destroy the germinative capacity of the seed as completely and irrevocably as fragmentation into many pieces.

Physical damage that does not immediately destroy the seed's germinative capacity can result in various sorts of structural defects in the seedlings produced. Some of these defects cause the seedling to be classified as abnormal or "non-germinable", but in other cases the

seedlings are considered normal although they might be stunted, or have drastically altered and less efficient root systems, and so on. It should also be recognized that while the declaration by an analyst that the seedling from a damaged seed is abnormal eliminates it from the "germination percentage" it does not eliminate it from the lot. Abnormal seeds germinate and produce plants that take up space and utilize light, water and nutrients without contributing much to yield - just like weeds.

Rupture, gouging or fracture of the seed coverings can have an effect on germination and emergence even though the embryonic axis and nutritive tissue are unaffected. Usually the effects are indirect. Cuts in cotton seed coats permit direct contact of embryonic tissue and sulfuric acid during acid delinting which produces necrotic lesions on the cotyledons and may destroy the root tip. Certain chemical seed treatments, especially some systemic insecticides, are more phytotoxic to damaged than non-damaged seed.

Rupture or fracturing of the seed coat also destroys the "barrier" protection of the seed coverings. One reason for the use of seed fungicides is to overlay a "chemical" barrier over gaps in the physical barrier of the coverings caused by cuts, ruptures, and fractures. Disruption of the physical barrier allows entry of soil borne microorganisms which can destroy the seed unless a chemical barrier is overlaid. A substantial portion of the fungicide treatments applied to seed, therefore, is to "cover up" mechanical damage.

Benefits of Mechanical Damage: It is somewhat ironic that as well as the damaging effects of mechanical abuse are understood, controlled mechanical damage is the center piece of several operations routinely done during conditioning of some seed kinds. Mechanical scarification of clover, alfalfa and vetch seed is done to increase germination by reducing hardseededness. Mechanical scarification, however, is nothing more or less than controlled mechanical damage which produces more good effects (permeable, germinable seed) than bad effects (severely damaged, non-germinable seed). While the short term benefits of mechanical scarification outweigh the adverse effects, the situation can reverse in the long term. Scarified seed do not store well. Acid scarification has somewhat the same effects as mechanical scarification and is used for the same purposes. Hulling of seed results in incidental damage, which again, can have an adverse effect on storability of the seed.

The protective role of the seed coverings is very important in our modern, mechanized agriculture. Adjustments in the various mechanical operations to take advantage of seed conditions that maximize resistance of the seed to mechanical forces (moisture contents of 13-16%) and/or to minimize the magnitude of the forces applied are critical features in quality assurance programs.

The containment and protective roles of the coverings of seed are well established and rather obvious. The failure of seed coverings to contain and/or protect as in a split bean seed is highly visible. The equally, or even more important regulator role of the seed coverings, however, is neither well known nor obvious.

Regulation

Seed coverings regulate the rate of water absorption and gaseous exchange by seed, and as a consequence of these regulatory aspects and others, the germination process is regulated. Most seedsmen are familiar with the "hard seeds" that occur in the legume family, okra and other kinds. A hard seed is a seed in which water absorption is regulated by the seed coverings to the degree that no water is absorbed, i.e,. the seed coverings are impermeable to water. Regulation of water absorption ranges even within the same seed kind from the impermeable level to a level where the entry of water is scarcely impeded by the coverings. Regulation of water absorption by the coverings regulates germination because absorption of water or rehydration is the crucial step for germination. A seed with a water impermeable seed covering, i.e., a hard seed, does not germinate - it is dormant, while the germination of seeds with a covering slowly permeable to water is delayed. These are rather straight forward, "expected" types of responses. An unexpected response is germination dysfunction and/or seedling damage as a result of insufficient regulation of the rate of water absorption by the seed coverings, i.e., too rapid absorption. Considerable evidence has been accumulating which implicates damage from too rapid water absorption in germination failure under wet and cool conditions. Key evidence in this area was reported by Tully, Musgrave and Leopold (Cornell U.) a few years ago. They demonstrated in most convincing ways that imbibitional chilling injury in soybean and pea seed was controlled by the rate of water absorption, hence, permeability of the seed coverings. The pea seed covering, for example, retarded water absorption enough to minimize chilling injury, while the non-pigmented seed coat of soybean did not. Nicking the pea seed coat negated its regulatory role and chilling injury was not prevented. Much earlier (1966) Pollock and others had shown that mechanically damaged lima bean seed are more susceptible to cool, wet conditions.

Considering the rather high percentages of mechanically damaged seed that can occur in cotton, soybean and peanut seed lots, and the frequency of cool, wet conditions at planting time, e.g., planting interrupted by a cool rain, we can speculate that too rapid absorption of water might be a major cause of poor stands. Seed treatment protects the imbibitionally injured seed from microorganisms but the damage is already done. Perhaps, water absorption retardant seed coverings are needed in such situations.

Seed coverings through their control of water absorption (liquid and vapor forms) can regulate the life span of seed. Seed of soybean

lines with even a moderate degree of hardseededness (say, 50%) retain their germination better under weathering pressure prior to harvest and during storage under warm, humid conditions.

The water absorption aspect of the regulatory role or function of seed coverings is deliberately modified or negated by scarification with highly beneficial results. Treatments that tighten-up rather than eliminate the regulation on water absorption imposed by the seed coverings might be equally beneficial under certain circumstances or situations, which need to be more clearly defined and characterized.

Gaseous exchange is regulated by seed coverings: more specifically, the absorption of oxygen. As in the case of regulation of water absorption, oxygen absorption can be regulated to the extent that insufficient oxygen is available at the crucial sites for germination and, thus, dormancy is imposed. It is very likely that even in non-dormant seed, oxygen absorption is restricted by the seed covering until it is ruptured by the emerging radicle. Enhancement of oxygen absorption prior to rupture of the covering could accelerate germination and, possibly, increase germination percentage. The products of anaeobic respiration are very damaging to low vigor, damaged seed.

Seed coverings act in several additional ways to regulate germination. There is substantial evidence that germination is prevented in some kinds of seed, i.e., dormancy imposed, by mechanical restriction of the seed coverings. The processes that lead to a release of dormancy, however, are not at all clear. For dormancy to be released, the mechanical strength of the coverings must be diminished in some way and/or the emergence force of the seedling must be increased. The seed coat can also regulate germination by acting as a light filter. Thick or pigmented seed coverings that exclude light or the effective wave lengths of light could hold light sensitive seed in a dormant condition. Finally, seed coverings regulate germination by serving as a respository or reservoir for inhibitors that migrate into the seed on wetting and block metabolic events critical for germination.

Summation

The coverings of seed are truly marvels of form and function but we shouldn't be content to just gaze on them with awe. Efforts to minimize damage to the coverings - except when needed to overcome dormancy - must be continued. And, careful thought needs to be given to the suitability of the coverings of major crop species in modern agriculture. Perhaps, better, or at least amended, seed coverings are needed.

COMPARISON OF NON-WRINKLED AND WRINKLED SOYBEAN SEEDCOATS BY SCANNING ELECTRON MICROSCOPY

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Abstract

Cross-sectioned soybean seed of the 'Bragg' and 'Davis' cultivars with either wrinkled or non-wrinkled seedcoats were examined by scanning electron microscopy for their seedcoat characteristics. The typical soybean seedcoat structure observed for both cultivars consisted of an outer cuticle with internal palisade, hourglass, and parenchyma cell layers. However, the layer of hourglass cells in both wrinkled and nonwrinkled seedcoats of both cultivars decreased gradually in thickness until it disappeared completely in the area opposite the hilum. In addition, hourglass cells in the area of seedcoat wrinkling in both cultivars appeared twisted, compressed, and distorted. The appearance of these cells may explain the wrinkled seedcoat condition which usually occurs opposite the hilum when seeds are exposed to alternate wetting-drying cycles. The role of the hourglass cells as a supporting, "cushion-like" mechanism is suggested.

Additional index words: Glycine max (L.) Merr., soybean seedcoat, cuticle, hourglass cells, palisade cells, parenchyma cells.

Exposure of soybean seed to alternate wet and dry weather while awaiting harvest after maturity causes seedcoat wrinkling which is referred to by Moore (6, 7) and Wolf et al. (10) as water damage. Moore (6, 7) pointed out that unequal expansion of the seedcoat during rehydration and dehydration leads to unequal stresses which causes wrinkling. The outer surface of the cotyledons just beneath the area of seedcoat wrinkling becomes damaged and may result in either abnormal seedling or complete absence of germination. Pereira (8) observed reduced seedling emergence for soybean seeds with wrinkled seedcoats compared to those with non-wrinkled seedcoats. Pereira (8) also stained seeds with both wrinkled and non-wrinkled seedcoats with 2, 3, 5 triphenyl tetrazolium chloride and observed discolored "bands" on the cotyledons corresponding to the same patterns of the visible wrinkled on the external surface of the seedcoat. These "bands" were atypical in their staining pattern, either intensely stained or almost white, and were invariably prominent on the cotyledonary area opposite the hilum (6, 7, 8).

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Recently, the scanning electron microscope (SEM) has been used in studying the structural features of soybean seedcoats (1, 9, 10) as well as assessing water absorption and disease infection in seeds (1, 4). Seedcoats of soybeans and legumes possess characteristic layers -the cuticle, and layers of palisade, hourglass and parenchyma cells (1, 2, 3, 4, 9, 10). It is not known, however, what happens to these layers when they are subjected to alternate rehydration-dehydration cycles. The objective of this study was to use SEM to examine modifications of the seedcoat structure that might be implicated with the wrinkling process.

Materials and methods

Soybean seeds of the 'Bragg' and 'Davis' cultivars were produced in 1981 at Mississippi State, MS. Seeds of both cultivars were sorted by hand into wrinkled and non-wrinkled categories according to the external appearance of their seedcoat.

Seeds were cross-sectioned transversely through the hilum with a single-edge razor blade and were mounted with the cut surface upwards on aluminum stubs with epoxy glue (Ross Chemical Co., Detroit, MI 48209). The specimens were coated with gold/palladium (60:40) in a Polaron E 5100 Series II Cool sputter coater (Palaron Equipment Ltd., Watford, England) and examined in a Hitachi HHS - 2 R Scanning Electron Microscope (Hitachi Electronics, Ltd., Tokyo, Japan) at an accelerating voltage of 20KV. Photomicrographs were taken with Polaroid type 55 P/N 4 x 5 Land film (Polaroid Corp., Cambridge, MA 02139) at a working distance of 15 mm.

Results and Discussion

The SEM micrographs revealed seedcoat patterns for both cultivars which were quite similar. The cuticle and palisade, hourglass, and parenchyma cell layers were highly developed at the subhilar region (Fig. 1 and 4), but the size of the hourglass cells gradually decrease and disappeared in the region opposite the hilum (Fig. 2 and 5). McEwen et al. (5) showed the existance of hourglass cells in faba beans (Vicia Faba L.) on the side directly opposite the hilum but made no reference to their size when compared to those in other regions of the seedcoat. During our work, however, we did not observe any hourglass cells in the area of the seedcoat directly opposite or distal to the hilum. In addition, a comparison of wrinkled and non-wrinkled seedcoats of both Davis and Bragg showed that the hourglass cells of the wrinkled and non-wrinkled seedcoats in the area where seedcoat wrinkling began to occur appeared compressed and twisted (Fig. 3 and 6). However, hourglass cells were not altered in non-wrinkled seedcoats.

The conspicuous hourglass cells of the subhilar region act like a "cushion" preventing the occurrence of wrinkles which have been identified by Moore (6, 7) as the consequence of successive cycles of rehydration and dehydration. Since there are no hourglass cells present in the region opposite the hilum, the expansion and contraction of the seedcoat cannot be "cushioned", and it is forced to wrinkle. Seeds with moisture contents below 18% are more susceptible to rapid rehydration-dehydration cycles which promote seedcoat wrinkling (Fig. 10), while seeds with moisture contents above 18% are less affected and exhibit little, if any, seedcoat wrinkling (Fig. 7). This suggests that seedcoat wrinkling does not occur in those seeds which are not yet sufficiently dry (mature) when rehydration-dehydration cycles occur during the critical post-maturation, pre-harvest interval just prior to harvest. This cyclic phenomenon exerts its greatest influence on those seeds which have dried down (matured) to field maturity, approximately 13-15% moisture. The cotyledonary cells underlying these wrinkles are subject to pressure which causes them to bruise or even die (Fig. 11 and 12). Thus, deterioration is initiated which eventually spreads throughout the entire seed, decreasing its quality and reducing field emergence (6, 7, 8). On the other hand, seeds not yet dry enough to be stressed by variable moisture do not exhibit seedcoat wrinkling and cotyledonary deterioration (Fig. 8 and 9).

Acknowledgements

The author fully appreciates the assistance of Dr. G. E. Tyson and Mr. M. Sullivan of the Electron Microscopy Center at Mississippi State University.

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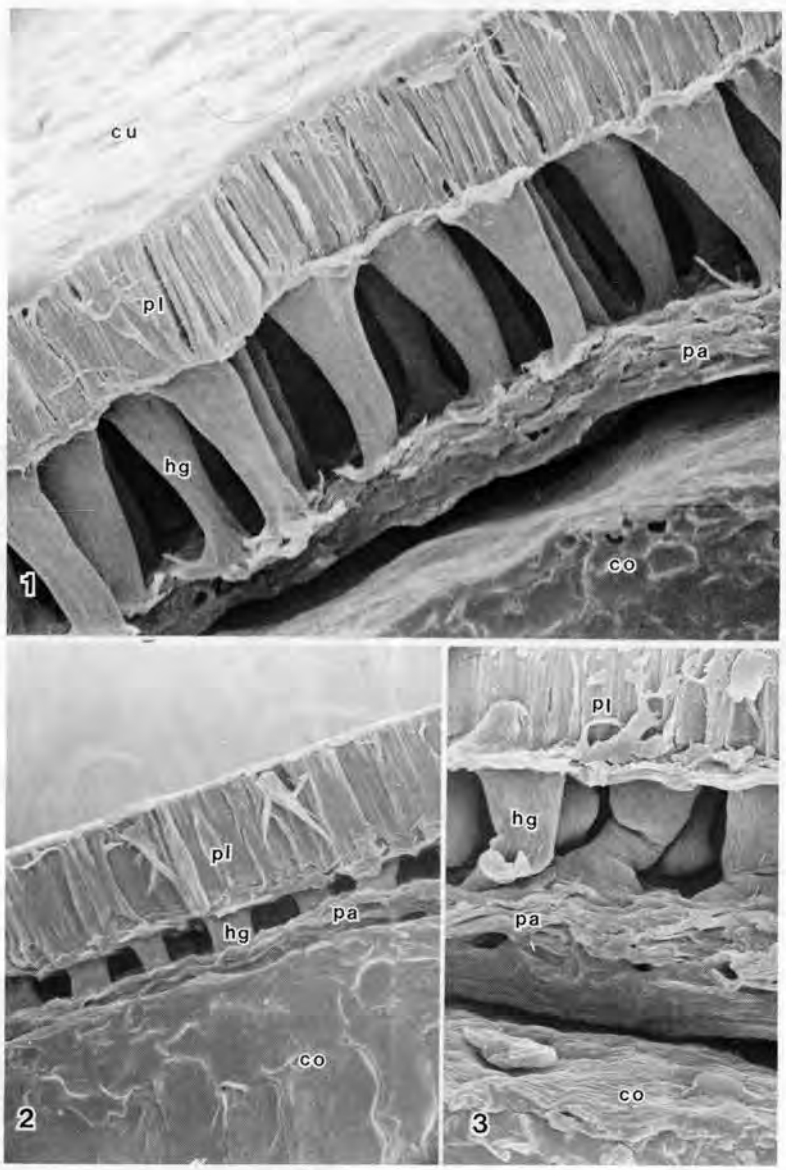

Fig. 1-3. SEM micrographs of seedcoat structure, cv. Davis. Fig. 1 at the subhilar region; X 250. Fig. 2 at an intermediary point between the hilum and its distal region; note that hourglass cells are visibly smaller; X 500. Fig. 3 wrinkled seedcoat near the subhilar region; note the compressed twisted hourglass cells; X 800. cu = cuticle; pl = palisade cells; hg = hourglass cells; pa = parenchyma cells; co = cotyledon.

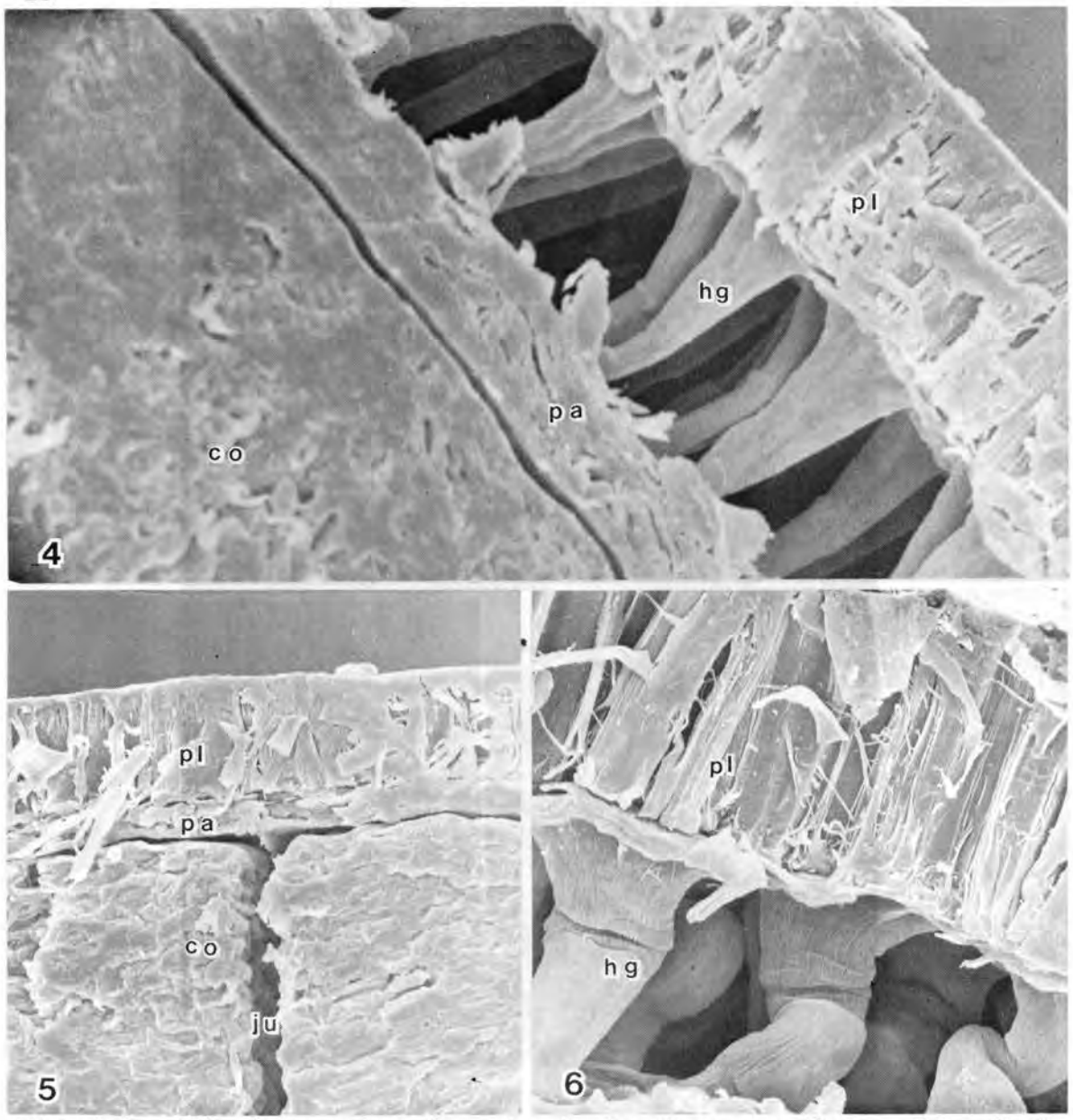

Fig. 4-6. SEM micrographs of seedcoat structure, cv. Bragg. Fig. 4 at the subhilar region; X 350. Fig. 5 at the region directly opposite the hilum; note the absence of hourglass cells; X 400. Fig. 6 wrinkled seedcoat near the subhilar region; note the compressed, twisted hourglass cells; X 850. pl = palisade cells; hg = hourglass cells; pa = parenchyma cells; co = cotyledon; ju = juncture between cotyledons.

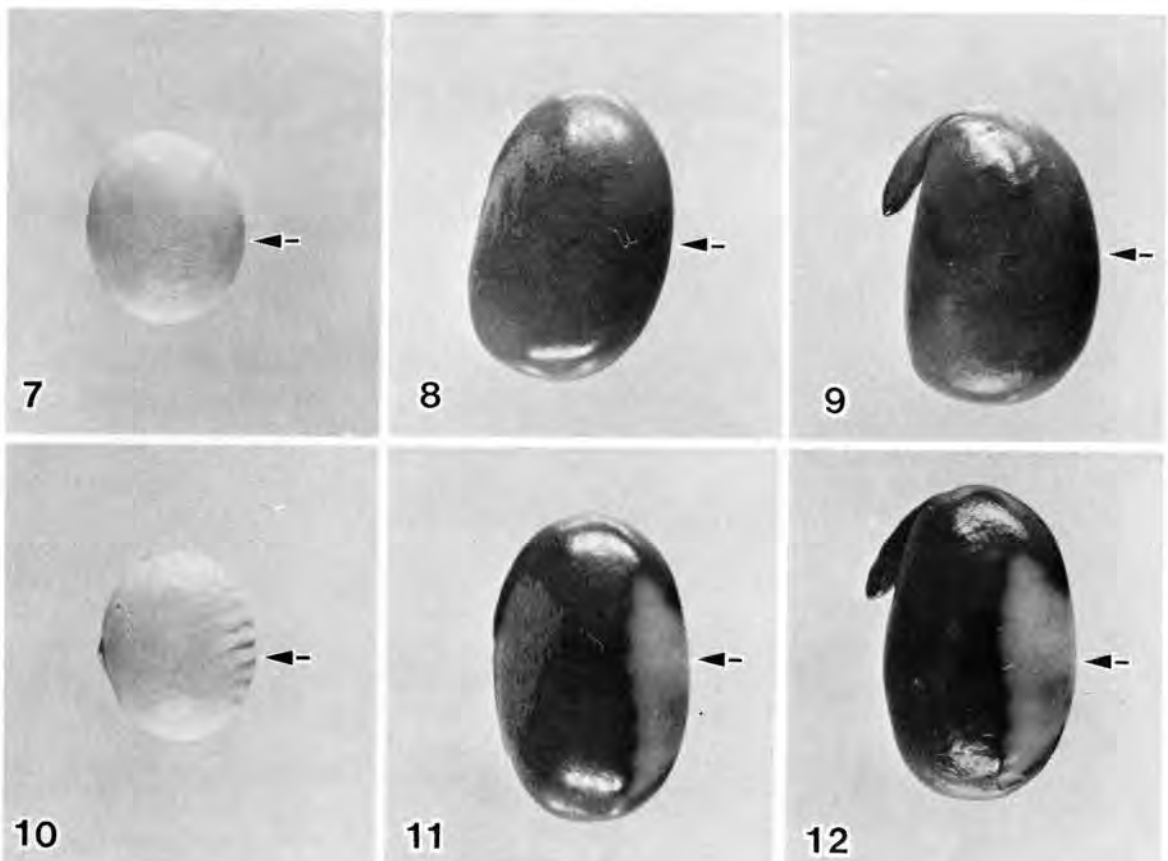

Fig. 7-9. Non-wrinkled seed of Davis showing smooth seedcoat (7), TZ stained seed with seedcoat intact (8), and TZ stained seed with seedcoat removed (9). Arrows point out absence of wrinkled seedcoat and areas of deterioration in TZ stained seed.

Fig. 10-12. Wrinkled seed of Davis showing wrinkled seedcoat (10), TZ stained seed with intact seedcoat (11), and TZ stained seed with seedcoat removed (12). Arrows point out wrinkled seedcoat and areas of deterioration just beneath wrinkled in TZ stained seed.

SYSTEMS FOR CROP VARIETY IDENTIFICATION

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Varietal identification is the cornerstone of pure seed production and certification because it:

- Indicates yield potential.
- Provides information on optimum crop establishment such as date of planting, row width, plant type, etc.
- Relates maturity and harvesting information.
- Identifies disease resistance.
- Suggests particular fertility regimes.

These parameters are essential components of any successful farming operation. A farmer recognizes that he must have assurance that the variety of seed purchased is the variety of seed desired. It was for this reason that the certification process was established. Farmers realize that certified seed has been inspected for trueness-to-type and can be confident of the quality of seed purchased.

In 1970, the United States Congress passed the Plant Variety Protection Act which had an immediate impact on the seed industry. The purpose of the Plant Variety Protection Act is "To encourage the development of novel varieties of sexually reproduced plants and to make them available to the public, providing protection available to those who breed, develop, or discover them, and thereby promoting progress in agriculture in the public interest." Clearly, this significant preamble was designed to encourage private seed companies to initiate their own breeding programs--a role which to that point in time had been fulfilled by public university and government breeders. For the first time, a private seed company which released a new variety could have it protected from competitor infringement for 18 years. To obtain Plant Variety Protection, however, the protected variety must meet the following three criteria:

(1) Novelty - Clearly distinct from all other varieties.

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(2) Stability - Sexually reproducible while retaining its essential and distinct characteristics.

(3) Uniformity - Variants are describable, predictable and commercially acceptable.

Recognizing the intended objective of the Plant Variety Protection Act to promote plant breeding programs within the private sector, how sucessfull has it been? One measure is to compare the number of companies with soybean breeding programs in 1970 as well as to identify the number and quality of breeders actively developing new soybean varieties today (Table 1).

There can be little question that the Plant Variety Protection Act has modified seed industry research programs to include a strong commitment to breeding. But this change in research personnel still fails to assess whether these efforts in breeding have been reflected in the release of new varieties.

Table 2 demonstrates that 230 new soybean varieties have been issued PVP certificates from 1971 to 1981! In addition to this remarkable increase in soybean germplasm, the trend is clearly apparent that many of these varieties were developed and protected during the last five years. It seems reasonable to assume that there will be a continuing increase in the development of new soybean varieties by the private seed sector in the foreseeable future.

However, this proliferation of newly developed soybean varieties has made taxonomic characterization of varieties via traditional field evaluation of morphological features increasingly inadequate.

Because variety identification plays an integral role in seed certification, the development of laboratory tests which provide improved differentiation has become necessary. Laboratory procedures furnish several additional characteristics useful for genetic purity determination and offer the promise of rapid and and inexpensive analyses for future use in variety identification.

At present, in order to determine if seed is genetically pure, a certification agency employs inspectors to make field observations of the morphological characteristics of crops grown for seed. However, field testing possesses several undesirable characteristics:

- The crop must be grown in areas where the variety is well adapted, under the best cultural practices, and during the proper growing season.

- The variety must be judged for 'trueness-to-type' at precise times.

Table 1. Effect of PVP on private soybean breeding programs.

Year	Number of Companies	Number of Breeders	Breeders With Ph.D.
1970	6	6	4
1983	28	60	29

Table 2. Soybean VP certificates issued from 1971 to 1981.

Year	Certificates	Year	Certificates
1971	9	1977	20
1972	8	1978	20
1973	13	1979	35
1974	15	1980	37
1975	11	1981	49
1976	13		
		TOTAL	230

- An individual who possesses a thorough knowledge of the variety is required for identification.

- Field testing generally requires at least six months for variety determination in order that all characteristics are expressed during a growing season.

- Field testing is expensive, requiring equipment, planting and harvesting personnel in addition to inspectors and land use.

- The number of morphological characteristics useful in variety characterization is no longer adequate for identification of all varieties.

Current soybean variety identification techniques are, for these reasons, inadequate. As a result, the development of laboratory tests to differentiate varieties has recently been emphasized (Payne, 1979; McDonald, 1979; Wagner and McDonald, 1981). Laboratory techniques offer the promise of being more rapid and less expensive than field testing. Further, analysis time is flexible and numerous additional traits useful in taxonomic characterizations are available.

The objective of this study was to examine and develop rapid, uncomplicated, inexpensive and repeatable means of differentiating soybean varieties which can be applied to seed certification and breeding programs. Much of the research presented in this study was initially reported by Wagner and McDonald (1982).

Materials and Methods

Samples included in the Tests

Soybean seeds harvested in 1977 and 1978 was requested from institutional growers or from seed companies. Thirty varieties from the 1977 harvest were received by February, 1978. The seed level for each variety, i.e., breeder, foundation, registered or certified, is provided in Table 3. Each of the varieties was tested in the field and the laboratory.

Twenty-nine 1978 varieties were received by April, 1979. Twenty-three of the 30 1977 varieties were included, bringing the total number of varieties examined to 36. Table 3 provides the seed level for these, each of which was tested in the field and laboratory.

All seed samples were stored at room temperature in the laboratory until used.

Table 3. Level of seed (C-certified, R-registered, F-foundation) from the 1977 and 1978 harvests.

Cultivar	Seed Level	Year(s) of Harvest	Cultivar	Seed Level	Year(s) of Harvest
Agripro 20	F	1977	Sloan	F	1978
Agripro 25	F	1977	S 1244	F/F	1977/1978
Agripro 26	F	1977	S 1346	F/F	1977/1978
Amsoy 71	F/F	1977/1978	S 1474	F/F	1977/1978
Beeson	F/F	1977/1978	S 1492	F/F	1977/1978
Calland	F/F	1977/1978	S 1578	F/F	1977/1978
Cumberland	F	1978	SRF 150-P	F/R	1977/1978
Elf	F	1978	SRF 200	F/F	1977/1978
FFR 111	F	1977	SRF 307-P	F/R	1977/1978
FFR 223	F/C	1977/1978	SRF 350	F/F	1977/1978
FFR 224	F/C	1977/1978	SRF 400	F/R	1977/1978
FFR 335	F/C	1977/1978	SRF 450	F/F	1977/1978
FFR 337	C	1978	Vickery	F	1978
FFR 444	F/C	1977/1978	Wayne	F/F	1977/1978
Matsoy	C	1977	Wells	F/F	1977/1978
Mitchell	F/C	1977/1978	Williams	F/F	1977/1978
Oakland	F	1978	Woodworth	F/f	1977/1978
P-61-22	F	1977			
Rockford	F	1977			

Field Tests

In order to verify that the varieties were labelled and identified correctly, field tests were performed for seeds received in both years. The field tests for the 1977 and 1978 varieties were planted on June 2, 1978 and June 5, 1979, respectively. One 3 m long row of each variety was planted. Seeds were planted at a rate of six seeds per 30 cm. Border rows were alternated with the rows of varieties, and two border rows were planted around the perimeter of the plot. Three morphological characteristics were visually observed in the field (stem pubescence color, leaf shape, and flower color) and compared to those outlined by the Ohio Seed Improvement Association (OSIA, 1977-80).

Laboratory Tests

1. Hilum color. A minimum of 10 seeds from each variety were examined and placed in one of five hilum color categories: clear, buff, brown, imperfect black and black (the imperfect black hilum is bordered by a brown line, distinguishing it form the completely black hilum).

2. Hypocotyl color. In order to determine hypocotyl color, a minimum of 10 seeds of each variety were placed in a watered medium composed of 1/3 sand, 1/3 soil, and 1/3 vermiculite, and allowed to germinate under fluorescent lighting (450 $Em^{-2}s^{-1}$). After seven to 10 days, hypocotyl color was examined and the varieties were placed in one of two categories, green or purple hypocotyl.

3. Peroxidase test. The method of Buttery and Buzzel (1968) was used to analyze peroxidase content. Seed coats were removed from a minimum of ten seeds from each variety with a razor blade. Each coat was then placed in an individual test tube. Ten drops of 0.5% (v/v) guaiacol were added to each tube. After 10 minutes, one drop of 0.1% (v/v) hydrogen peroxide was added to each tube. Cultivars were placed into one of two groups based on the formation (positive) or absence (negative) of a reddish brown color.

4. Electrophoresis. The polyacrylamide gel electrophoresis apparatus used in this study included a Buchler Instrument chamber which held 18 electrophoresis tubes and had a total buffer capacity of 1.71. The power supply was ISCO model 493.

(a) Gel preparation. For each electrophoretic run, 18 cylindrical glass tubes 7.5 cm long with an inner diameter of 5 mm were thoroughly washed, dried, inserted into serological stoppers and placed into a gel stand. Forty ml of 7.5% acrylaminde lower gel solution were prepared by mixing one part A to one part C to two parts fresh F (see appendix). The F solution was always added last. Using

a disposable pipette, the gel solution was added to the 6 cm mark on the tubes, making sure that no air bubbles were trapped in the tubes. One drop of distilled water was then added in order to deter formation of a meniscus on the gel's upper surface. The appearance of a sharp boundary line approximately 2 mm below the top of the gel 10 minutes to one hour later indicated that the gel had polymerized. If polymerization did not occur within one hour, the gels were placed in a convection oven set at 34C for one hour.

After lower gel polymerization was complete, the liquid on top of the gel was removed with a flick of the wrist and the tubes were placed back into the holder. Forty ml of 2.5% acrylamide upper gel solution were prepared by combining one part of B, two parts of D, one part of E and four parts of distilled water (see appendix). Six mm of this solution were pipetted onto the top of the lower gel, and one drop of distilled water was added to prevent meniscus formation. The gels, in the stand, were then placed under a flourescent lamp for 30 minutes, allowing the upper gel to photopolymerize. When ready, the upper gel appeared opaque. Prior to placing the tubes in the electrophoresis apparatus, the liquid on top of the gel was removed with a flick of the wrist. The gels were then used within three hours. If not, they were placed in a plastic bag and refrigerated overnight.

The tubes containing gels were placed in the grommets in the upper buffer chamber of the elctrophoresis apparatus. Enough tris-glycine buffer (solution G--see appendix) was added to the lower plastic dish so that the tubes made contact with it. The upper buffer chamber was replaced on the stand, and enough tris-glycine buffer was added to easily cover the tops of the tubes. Any air bubbles in the tops of the tubes were removed with a pipette. With a small syringe, 0.05 ml of a concentrated protein extract in a buffer specific for he protein being analyzed was added to the top of each of the gels in the apparatus. The syringe was rinsed with distilled water between sample application in order to avoid contamination. After all the samples were applied, a drop of tracking dye (0.001% (w/v) bromophenol blue, 10% (w/v) in sucrose was pipetted onto the top of each gel. Because it is a highly charged, small molecule, the tracking dye migrated faster than the proteins in the sample, and therefore, monitored the progress of electrophoresis.

The electrodes were then attached, positive polarity to the lower dish, negative to the upper, and the power supply was turned on to 60 mA constant current. This allowed approximately 3.3 mA to run through each of the 18 gels.

After approximately 65 minutes, the tracking dye reached the bottom of the gel tubes. The power supply was turned off and the electrodes detached. The tubes were removed form the apparatus. The gels were excised, or rimmed, by inserting a hypodermic needle attached to a water filled syringe between the gel and the glass tube.

The needle was held steady as the tubes were rotated, causing the gel to be detached from the glass tube. The gels were then placed into small glass test tubes and were stained according to the particular protein being analyzed. In cases where the stain was permanent, the gels were analyzed spectrophotometrically, measuring absorbance at an appropriate wavelength. In this manner, spectrophotometric scans, which represented the banding patterns, were achieved.

Zymograms, pictorial representations of banding patterns, were drawn for ephemeral isozyme stains which did not allow spectrophotometric analysis.

RF values ($RF = \frac{\text{distance traveled by protein}}{\text{distance traveled by tracking dye}}$) were also calculated for protein bands of interest. Gels were photographed immediately after staining was complete.

Two isozyme systems present in the unimbibed soybean seed were analyzed: B-amylase and urease.

(b) Preparation of the seed protein samples.

(1) B-amylase. An individual sample was prepared by grinding three unimbibed seeds of each variety into a fine powder with mortar and pestile set in ice. The powder was then mixed with 6.0 ml of buffer solution which consisted of an equal mixture of 0.1 M sodium acetate and 0.1 N acetic acid made of 10% (w/v) in sucrose (pH 5.0) and maintained at 5C (Larsen, 1967). The addition of sucrose ensures that the sample will fall to the top of the gel when applied. The mortar and pestle were rinsed between each exraction in order to avoid sample contamination. The homogenates were placed into centrifuge tubes. If centrifugation was not applied immediately, the tubes were placed in ice. Each of the samples was centrifuged at 20,200 x G at 5C for 10 minutes. The centrifuged samples were then placed in ice until ready for application to the polyacrylamide gel. All samples were prepared fresh daily. A minimum of 15 seeds of each variety were analyzed for B-amylase.

(2) Urease. An individual sample was prepared by grinding three unimbibed seeds of each variety with a mortar and pestle set in ice. The powder was then mixed with 6.0 ml of distilled water made 10% (w/v) in sucrose, and maintained at approximately 5C (Buttery and Buzzel, 1971). The soybean material and extractant solution were combined with the pestle. Samples were centrifuged as described previously. Again, all samples were prepared daily. A minimum of 15 seeds of each variety were analyzed for urease.

(c) Staining procedures.

(1) B-amylase (general protein). After removal of the glass tubes, each gel was soaked for one to eight hours at room temperature in 8 ml of staining solution composed of 0.1 g Coomassie Brilliant Blue in 10 ml of ethanol and combined with 250 ml of 12% (w/v) trichloroacetic acid (Bashuk and Zillman, 1978). After the dark blue bands were resolved, the gels were placed in distilled water. Spectrophotometric scans were made at a wavelength of 540 nm.

(2) Urease. Each gel was soaked for 10 minutes at room temperature in 8 ml of staining solution consisting of 25 mg cresol red dissolved in 90 ml of 0.2 m Na acetate buffer (45 ml 0.2 M acetic acid + 45 ml 0.2 M Na acetate), and 60 ml 7% (v/v) acetic acid (Buttery and Buzzell, 1971). The gels were then quickly transferred to 8 ml of a solution consisting of 1.6 g urea, 0.1 g Na_2 EDTA, and 25 mg cresol red dissolved in 150 ml distilled water. Within five to 20 minutes, bright purple red bands were resolved. The banding pattern for urease was recorded immediately after resolution as the solution quickly caused the entire gel to stain. Due to the ephemeral nature of the stain, spectophotometric scans were not made.

Results

Field Tests

Results of the field tests were consistent with variety characteristics outlined by the Ohio Seed Improvement Association, with two exceptions. 'Agripro 20' which was listed as possessing a brown hilum, was placed in the buff category in this study, as well as in another (Payne, 1979). In addition, 'SRF 307-P', listed as having a buff hilum, was placed in the brown grouping (ICIA, 1978).

Laboratory Tests

1. Hilum color. Hilum color determination categorized the Ohio soybean varieties as indicated in Table 4. The 36 soybean varieties were subdivided into five groups. The largest group (black) contained 14 varieties. Results for the same variety from the two different growing seasons were identical.

2. Hypocotyl color. Hypocotyl color determination categorized the 36 Ohio soybean varieties as indicated in Table 5. A total of 27 varieties were classified as purple and nine varieties possessed green hypocotyls. A correlation between the seedling hypocotyl color and the flower color was shown to exist. Cultivars possessing green hypocotyls produced white flowers while varieties having purple hypocotyle produced purple flowers. Results for the same variety from the two different growing seasons were identical. The genetic linkage

Table 4. Differentiation of 36 soybean varieties certified in Ohio based on five hilum color categories (number in parenthesis indicates the total for each group).

Hilum Color				
Clear (9)	Buff (2)	Brown (5)	Imperfect Black (6)	Black (14)
Amsoy 71	Agripo 20	Mitchell	Agripo 25	Calland
FFR 111	S 1492	Sloan	Agripo 26	Elf
FFR 223		S 1474	Beeson	FFR 224
Matsoy		S 1578	Cumberland	FFR 335
P-61-22		SRF 307-P	Rockford	FFR 337
S 1346			Wells	Oakland
SRF 150				S 1244
SRF 200				SRF 350
Vickery				SRF 400
				SRF 450
				Wayne
				Williams
				Woodworth
				FFR 444

Table 5. Differentiation of 36 soybean cultivars certified in Ohio based on hypocotyl color and seed coat peroxidase reaction (number in parenthesis indicates the total for that group).

Hypocotyl Color		Seed Coat Peroxidase	
Purple (27)	Green (9)	Positive (16)	Negative (20)
Agripro 20	FFR 335	Agripro 20	Agripro 25
Agripro 25	FFR 337	Amsoy 71	Agripro 26
Agripro 26	Sloan	Cumberland	Beeson
Amsoy 71	S 1492	FFR 111	Calland
Beeson	SRF 307-P	FFR 223	Elf
Calland	SRF 350	Matsoy	FFR 224
Cumberland	Wayne	Mitchell	FFR 335
Elf	Williams	P-61-22	FFR 337
FFR 111	Woodsworth	Rockford	Oakland
FFR 223		S 1244	Sloan
FFR 224		S 1578	S 1346
Matsoy		SRF 150	S 1474
Mitchell		SRF 200	S 1492
Oakland		SRF 450	SRF 307-P
P-61-11		Vickery	SRF 350
Rockford		Williams	SRF 400
S 1244			Wayne
S 1346			Wells
S 1474			Woodworth
S 1578			FFR 444
SRF 150-P			
SRF 200			
SRF 400			
SRF 450			
Vickery			
Wells			
FFR 444			

between imperfect black hila and purple hypocotyl color, demonstrated in past work (Bernard and Weiss, 1973), was substantiated.

3. Peroxidase test. The peroxidase test grouped the 36 varieties into two categories as indicated in Table 5. Sixteen varieties yielded a positive peroxidase reaction; 20 varieties demonstrated a negative reaction. Results for the same variety from the two different growing seasons were the same.

4. Electrophoresis.

(a) B-amylase. Two patterns resulted when gels were stained for general protein. One exhibited a fast moving B-amylase band (RF = 0.51), the other a slow moving band (Rf = 0.46), as indicated by Figure 1.

The 36 varieties were categorized as possessing the fast or slow moving B-amylase band as indicated in Table 6. Twenty-eight varieties possessed a fast moving, B band; eight varieties demonstrated a slow moving, A band. Banding patterns within the same variety did not differ among growing seasons.

(b) Urease. Two isozyme banding patterns resulted when gels were stained for urease. One exhibited two bands (Rf = 0.11, 0.30); the other, one band (Rf = 0.30), as indicated by Figure 2. Spectorphotometric scans were attempted but did not succeed due to the ephemeral nature of the urease stain.

The 36 varieties were categorized as possessing the two or one band(s), as indicated in Table 6. Three varieties exhibited either banding pattern, i.e., seed urease varied. Since the seed used was deemed pure, these varieties apparently possessed the genetic ability to produce either urease banding pattern. Seventeen varieties possessed two bands; 16 varieties demonstrated one band. Banding patterns did not differ within the same variety from different growing seasons.

Summary of results. Combining the data from the five tests successful in differentiating soybean varieties in this study culminated in the separation depicted in Figure 3. Of the original 36 varieties examined, 15 were identified using the five tests in this identification system. Further, 22 groupings were established with no grouping possessing more than six varieties.

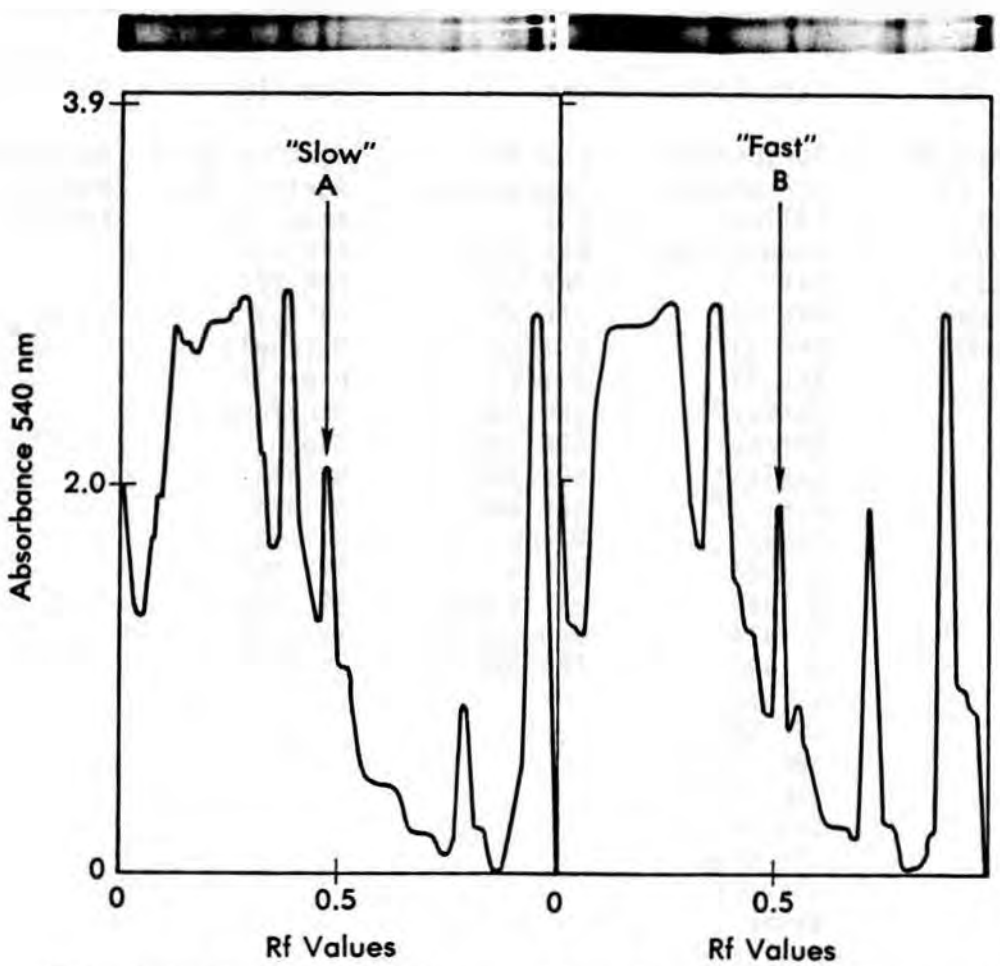

FIG. 1.—Spectrophotometric scans and photographs of the two B-amylase banding patterns of soybean cultivars, slow (A) and fast (B).

Table 6. Differentiation of 36 soybean cultivars in Ohio based on electrophoretic analysis of B-amylase and urease, extracted from the unimbibed seed (number in parenthesis indicates the total for that group).

B-Amylase		Urease		
Slow (8)	Fast (28)	One (17)	Two (16)	Both (3)
Agripro 20	Agripro 25	Calland	Agripro 20	Agripro 26
Amsoy 71	Agripro 26	Cumberland	Agripro 25	Beeson
Beeson	Calland	Elf	Amsoy 71	FFR 335
FFR 111	Cumberland	FFR 224	FFR 111	
FFR 223	Elf	FFR 337	FFR 223	
Rockford	fFR 224	Oakland	Matsoy	
SRF 200	FFR 335	S 1244	Mitchell	
Wells	FFR 337	S 1492	P-61-22	
	Matsoy	SRF 150	Rockford	
	Mitchell	SRF 307-P	Sloan	
	Oakland	SRF 350	S 1346	
	P-61-22	SRF 400	S 1474	
	Sloan	Wayne	S 1578	
	S 1244	Wells	SRF 200	
	S 1346	Williams	SRF 450	
	S 1474	Woodworth	Vickery	
	S 1492	FFR 444		
	S 1578			
	SRF 150			
	SRF 307-P			
	SRF 350			
	SRF 400			
	SRF 450			
	Vickery			
	Wayne			
	Williams			
	Woodworth			
	FFR 444			

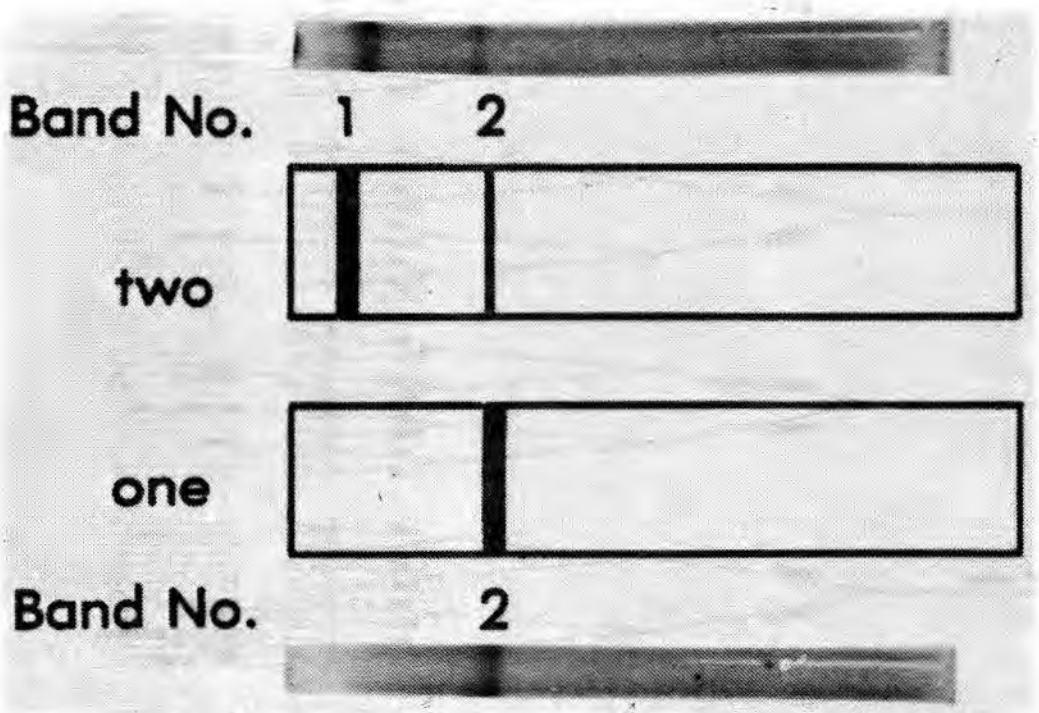

FIG. 2.—Zymograms and photographs of the two urease banding patterns of soybean cultivars, two and one.

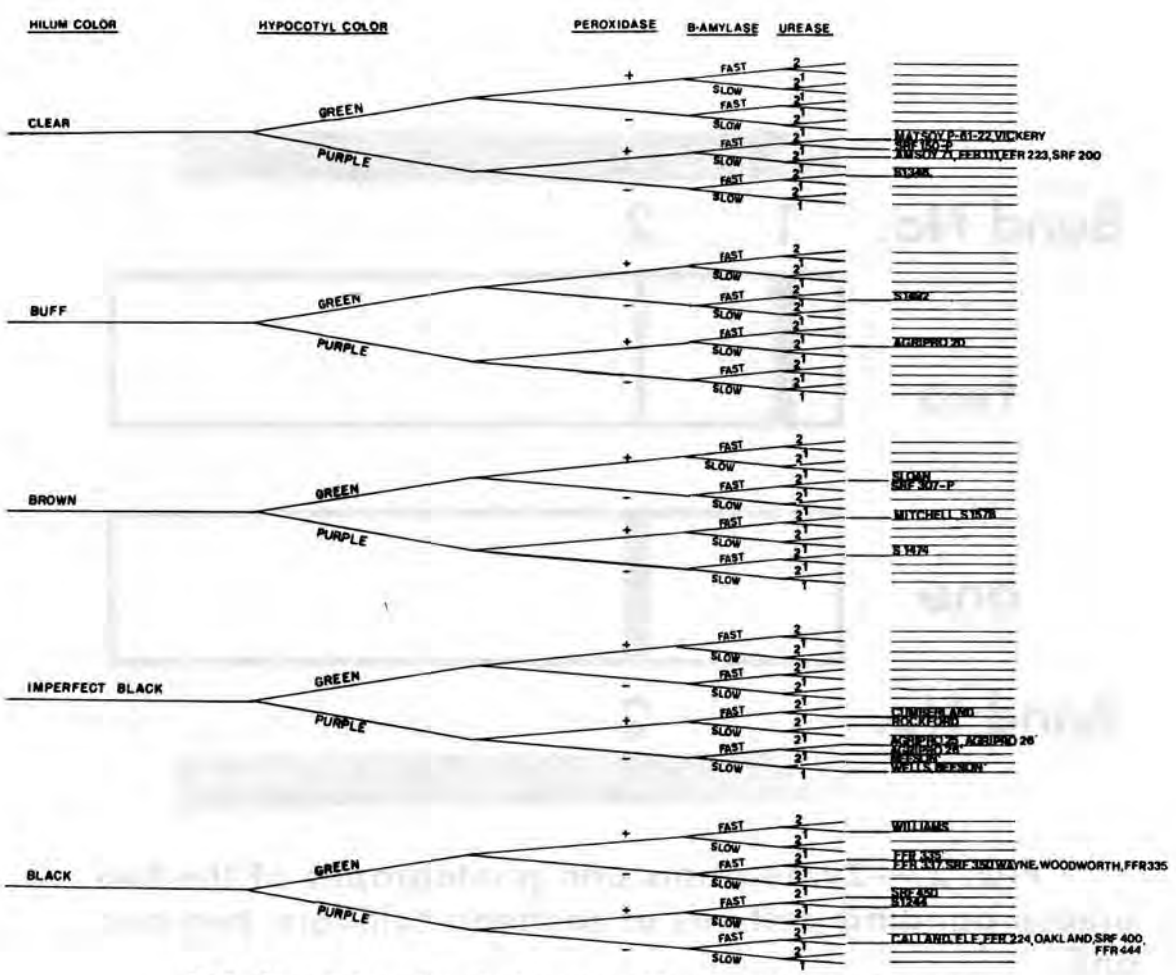

FIG. 3 —Schematic diagram illustrating the separation of 36 soybean cultivars via laboratory tests.

Discussion

Laboratory tests

A test useful for variety identification should possess several characteristics. It should be relatively uncomplicated, quick, consistent and inexpensive to perform. The test should also allow immediate observation of 'off-types'. Finally, if possible, the feature under examination should be possessed by individual plants or plant parts. Since it is unlikely that any single test will completely separate all varieties, several tests were examined in this study. Unimbibed seeds were used for all electrophoretic protein determinations because they are relatively stable physiologically and, therefore, were expected to provide repeatable results under standardized conditions. Further, in general, tests which yielded qualitative results, e.g., type of isozyme present, type of pigment present, etc., were employed, because qualitative data are less subject to such factors as seed vigor, storage, etc., than quantitative parameters. Finally, testing seeds of the same variety from different years allowed a comparison of results from different seed lots, addressing the question of repeatability between growing seasons.

The hilum color test was useful, but possessed several undesirable characteristics. Treated seed masked the hilum such that categorization was difficult. In addition, the difference between a buff and a brown hilum was minimal and differentiating the two was difficult. However, untreated, healthy seed, and experience, the hilum color test is a valuable technique for distinguishing varities. Hilum color is reportedly controlled by the alleles of four genes, some of which are pleiotropic (Bernard and Weiss, 1973).

The hypocotyl color test, although requiring a minimum of seven days to perform, proved to be a reliable method for separating soybean varieties. However, the separation resulted in only two groupings, with a large majority of varieties falling into the purple hypocotyl category (Table 5). Still, because of the association between flower color and hypocotyl color, this test is much more rapid than field observations. It has been reported that hypocotyl pigmentation is a result of the pleiotropic effect of one gene (Benard and Weiss, 1973).

The peroxidase test emerged as a useful assay for variety identification. Results obtained were consistent, but only when great care was taken to remove and test only the seed coat and none of the cotyledonary tissue. The latter yields a positive peroxidase test regardless of the seed coat reaction. Inheritance of peroxidase activity has been shown to be monogenically controlled (Buttery and Buzzell, 1969).

Electrophoresis proved to be an excellent means of characterizing variations in protein content among soybean varieties. The relatively low equipment cost, swiftness of analysis, ease of operation and ability to analyze simple seed protein samples repeatably contributed to the feasibility of its use for variety identification. Variations among varieties were detected for two isozyme systems, B-amylase and urease. In past work (Bernard and Weiss, 1973; Larsen and Caldwell, 1968), the B-amylase band was shown to be controlled by two codominant alleles at a single locus. Further, varieties with black, brown or buff hila exhibit the slow B-amylase band, while varieties with clear or imperfect black hila possess either the slow or fast B-amylase band (Payne, 1979).

The banding pattern achieved for soybean seed urease labelled "two" in this study differed from that reported originally by Buttery and Buzzell (1971). The former study resulted in two banding patterns, one with a fast moving band, another possessing a band of slower mobility. The urease banding pattern was shown to be monogenically controlled, the fast migrating band dominant over the slow moving band. In the present study, two bands were resolved for varieties deemed by Buttery and Buzzell as possessing the slow moving band. Similar results have been reported in other studies (Payne, 1979). It is possible that the slow moving band may dissociate due to factors such as the buffer employed, stability of the molecule, etc., producing a faster moving artifact (Buttery and Buzzell, 1971).

The separation of the varieties using the laboratory tests demonstrated in this study shows considerable improvement over the separation of the same varieties achieved via field testing. As indicated in Figure 4, the use of hilum color, flower color, leaf shape and stem pubescence color, the four most commonly employed characteristics in field testing, separates the 36 varieties in 13 groups. Only six varieties are isolated exclusively. The largest number of varieties remaining in any one group is six. Laboratory testing is, therefore, a more effective means of differentiating varieties in terms of the number of varieties which may be exclusively identified.

Feasibility of Laboratory Testing Procedures

Laboratory tests offer several important advantages over field testing in terms of effectiveness of identification, distinct and readily observable characteristics, and use of space. In addition to the electrophoretic analyses employed in this study, other electorphoretic tests have been reported as useful in soybean variety differentiation (Gorman and Kiang, 1977; Payne and Koszykowski, 1978). although experimentation has generally not been performed with soybean seeds, chromatographic (Buttery and Buzzell, 1973; Stewart, Asen, Massier and Norris, 1980) and serological (Esposito, Ulrich and Burrell, 1966) procedures have demonstrated taxonomic utility within

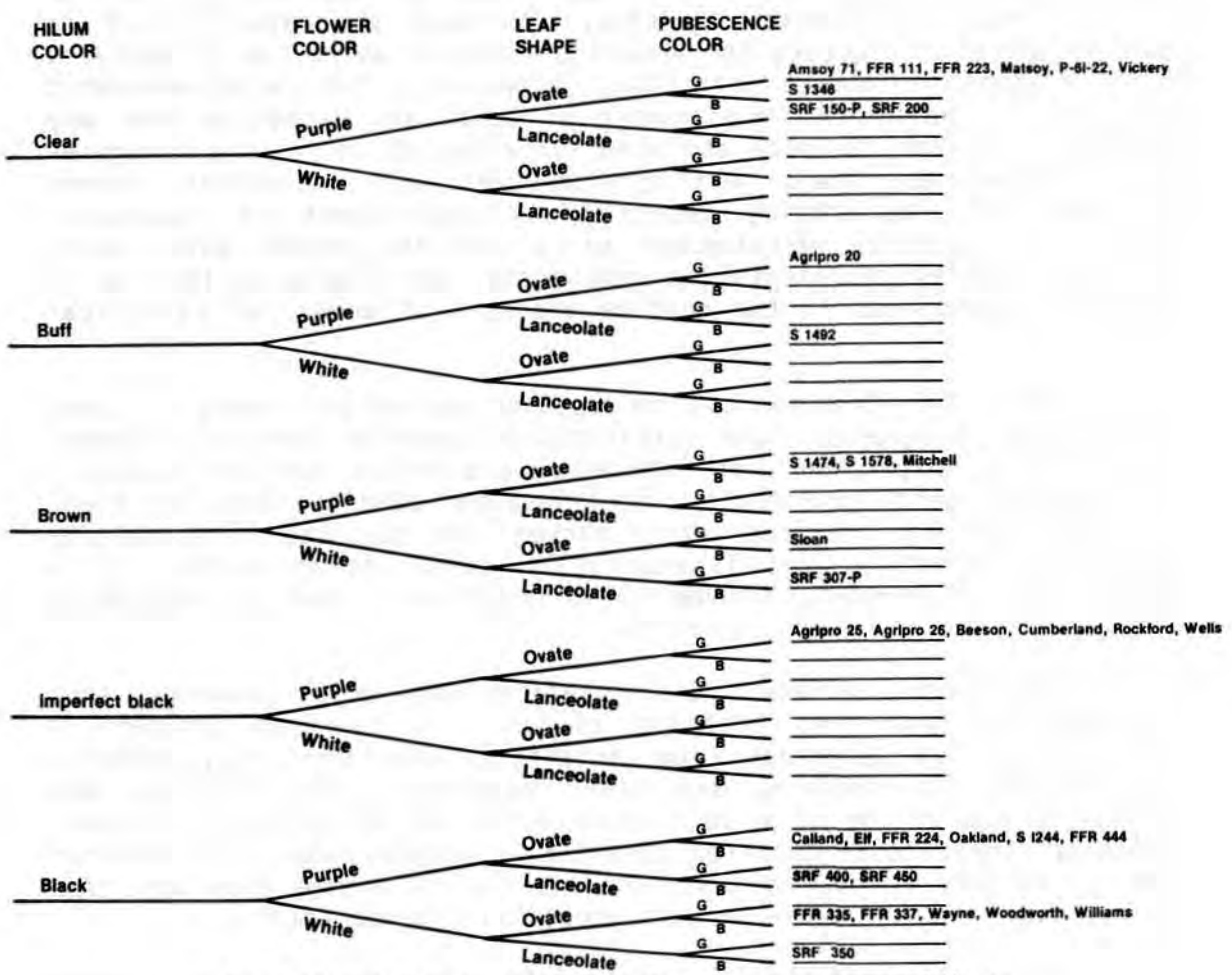

FIG. 4.—Schematic diagram illustrating the separation of 35 soybean cultivars via field tests.

several other crop species. Cytological (Davis and Heywood, 1965; Will, Kronsted and Tekrony, 1967; Solbrig, 1968) and ultrastructural (Chuang and Heckard, 1972; Krause, 1978; Newell and Hymowitz, 1978) methods also offer great potential for reliable intraspecific identification.

There are, admittedly, many unanswered questions regarding the use of laboratory tests for seed certification. The laboratory testing format must be feasible in terms of time, cost and logistical considerations. Assuming identical sample size, laboratory testing procedures cannot presently compete in terms of cost and time with the field sequential sampling method developed by the Association of Official Seed Certification Agencies. Although the material cost is low for laboratory testing the number of samples which can be analyzed in a reasonable amount of time, especially for electrophoretic analysis, is small. A large number of tests and excessive time are required. However, as more and more varieties of increasing homogeneity are developed, field testing procedures will undoubtedly become less adequate, encouraging technological improvement of laboratory tests. In addition, development of a sampling method which would require a smaller representative sample size would enhance the use of laboratory techniques in the routine analysis of seeds for certification.

Laboratory testing can be applied to other facets of seed certification programs. Some certification agencies currently augment initial field inspection with laboratory procedures such as hypocotyl color and the peroxidase tests. Certification agencies also may field test seed from the previous year's harvest for purposes of establishing variety purity. This is especially useful in determining if a certain lot of breeder, foundation or registered seed is adequately pure for further seed multiplication.

Laboratory variety identification not only benefits seed certification, but crop breeding as well. The crop breeder is interested in developing new crop varieties. Laboratory tests offer a quick method of screening new plant genotypes, and detecting any changes in the genome of a seed stock as it is multiplied or stored. Similarly, these tests offer an essentially endless source of information to variety review boards, which serve to ensure that new crop varieties are unique in one or more genetically based traits.

There are, admittedly, constraints upon the total replacement of field testing by laboratory testing for variety identification. However, based upon the results reported in this study and others, laboratory measures may serve as a viable supplement to present seed testing programs, and are likely to play an increasingly important role in the future.

Acknowledgements

This research was supported, in part, by the Ohio Seed Improvement Association Research Foundation, Dublin, Ohio.

Appendix

Procedures for preparing 7.5% acrylamide lower-gel, pH 8.9; 2.5% acrylamide upper gel, pH 6.9; and tris glycine buffer, Ph 8.3.

Solutions

Lower Gel		Upper Gel	
A. IM HCl	24.00 ml	B. IM H_3PO	25.60 ml
Tris	18.20 g	Tris	05.70 g
TEMED*	00.23 ml	TEMED*	00.46 ml
Water to 100 ml (pH 8.9)		Water to 100 ml (pH 6.9)	
C. Acrylamide	30.00 g	D. Acrylamide	10.00 g
Biasacrylamide	00.80 g	Bisacrylamide	02.50 g
Water to 100 ml		Water to 100 ml	
F. Ammonium persulfate	00.14 g	E. Ribofavin	4.00 mg
Water to 100 ml		Water to 100 ml	
G. Buffer (ph 8.3)			
Tris	03.00 g		
Glycine	14.40 g		
Water to 100 ml			

*TEMED is N, N, N', N' tetramethylethylenediamine.

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QUALITY ASSURANCE OR QUALITY CONTROL

Charles C. Baskin[1]

The term quality control has been used in the seed industry for many years whereas the term quality assurance is relatively new. What might be the differences in the two concepts? Everyone has a quality control program. These will range from very detailed, very sophisticated to barely meeting the minimum requirements of market seed. The concept of quality assurance implies that the efforts of a seed company are directed toward supplying the buyer with a higher quality, uniform product that will perform well in the field under a variety of conditions.

What, then, is involved in a quality assurance program? High quality must be the goal and must be ever present in the minds of everyone involved in the seed program.

Let's begin with field selection. Seed should be a more valuable commodity than grain, therefore, our most productive fields should be selected for seed production. Consideration must be given to weed problems, especially noxious weeds. Difficult weed problems should be avoided if at all possible. It is much simpler to avoid these than to try to deal with them in the crop or trying to remove them from the harvested seed.

Follow the best production practices that are available to you. Plant good quality seed. Have a good weed control program. Weeds are not only a problem in the seed, they reduce yields and may even contribute to disease and insect problems. An insect control program will also be necessary on certain crops to optimize yields and maintain quality.

Application of fungicides may be necessary in some crops such as soybeans and wheat. Defoliation in crops such as cotton, desiccation in other crops. There are several sources of information available to you for the latest in crop production recommendations. State extension services and experiment stations provide a wealth of information on all phases of crop production, variety responses, harvesting, storing and other areas. Private consultants and various companies can help formulate good pest control program. Field inspections are a a must throughout the growing season. Timing depends on the crop. You must know what you have in the field particularly from a genetic purity stand

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point and from a weed standpoint. Do your fields meet the standards necessary to produce the quality seed you want?

If you need to establish standards, the respective Seed or Crop Improvement associations have standards as does the Association of Official Seed Certifying Agencies. These can provide some basis for establishing field standards or in most instances may be adequate field standards if you are not participating in your state's certification program. Certainly consideration should be given to participation in a certification program in most states.

Timely harvesting is most critical. Seed of most crops will reach physiological maturity when seed moisture content is between 25 and 35%. For most crops this is too high for harvest. There are some exceptions such as corn that is harvested in the ear at 30 plus percent seed moisture, dried on the cob, then shelled. Generally, we wait until seed have reached 16 to 18 percent moisture or less before harvesting. Once seed have reached physiological maturity, they peak in germination and quality (vigor). From this point, loss in quality (deterioration) begins. Seed are essentially stored in the field from physiological maturity until harvest. The amount of deterioration (quality loss) depends on field conditions. It will be quite rapid if conditions are warm and humid to quite slow if conditions are cool and dry. Whatever the field conditions, this is not a desirable place for seed storage.

An example of deterioration related to field conditions is presented in Table 1. This test was conducted in Mississippi but the relativity of the results are applicable anywhere.

Harvesting is a very critical time in the life of a seed. Mechanical damage is one of the primary reasons for loss in quality in combining and handling. Damage of soybeans, for example, is negligible at seed moisture contents of 14 to 16 percent, is minimal at 12 percent but at 10 percent or less can be quite severe. The reduction of germination in germination in soybean seed as related to handling and moisture content is presented in Table 2. Harvesting corn seed with a combine as opposed to harvesting the ear, drying and then shelling can make a tremendous difference in the amount of mechanical damage. Field conditions can change rapidly from morning to noon to afternoon. It may be necessary to change combine settings during the day to minimize damage. The grain tank should be monitored regularly with a fragile crop like beans to be sure excess damage is not occurring, less with a crop like wheat although damage can occur to any seed.

Some seed must be dried. Corn, rice, and sometimes many other seeds require drying to adjust seed moisture content to a safe storage level. Drying temperatures are critical. Underdrying results in seed too high in moisture to store safely. Over-drying can cause quality losses in mechanical damage, even death and monetary losses in weight. If seed are held in storage for a period of time before conditioning and

Table 1. Effect of weathering on moisture content (M.C.) and germination of seed of the Hill and Bragg soybean varieties.

Date of Harvest[a]	Hill		Bragg	
	M.C.	Germination %	M.C.	Germination %
9/15	26	96		
9/22	13	97		
9/29[b]	17	90		
10/6[b]	20	78		
10/13	11	76	26	98
10/20[b]	19	71	18	98
10/27	12	53	13	93
11/3[b]	14	37	14	92
11/10			12	92
11/17[b]			20	89
11/24[b]			13	86
12/1			15	87
12/8			11	84
12/15[b]			14	84

[a]Seed hand harvested and threshed, then cleaned with hand screens and aspirator before germination test.

[b]One or more rains during preceding week.

Table 2. Relation of seed moisture content and force of impact (height of drop) to loss of germinability of soybean seed dropped onto a hard surface.

Seed Moisture Content (%)	Height of Drop (ft.)				
	0	5	10	10(2X)[a]	20
	----------% Germination----------				
8	98	88	78	65	70
10	98	90	82	73	73
12	98	97	94	88	87
14	98	97	97	96	97

[a]Seed dropped twice from height of 10 ft.

bagging, aeration is necessary to maintain quality. Stored grain insects can also be a problem. Regular monitoring is necessary to guard against insect losses.

Conveying equipment must be in good repair and properly adjusted to prevent mechanical damage. This is an area where improper adjustment can cause severe mechanical damage.

Adjustment of conditioning equipment is important to remove the materials you want to remove from the seed lot. (I am assuming that plant supervisors and equipment operators are knowledgeable enough of the various kinds of machines to know what can and can't be done.) I have been in conditioning plants where the cleaning equipment wasn't much more than a conveyor.

Once seed are conditioned and bagged, good storage conditions are necessary until seed are shipped.

The assurance of quality requires a well organized testing program. The organization and logistics of your operation will determine the organization of this phase of your program.

If you are dealing with contract growers that store seed on their premises, you can determine seed quality before bringing it to the plant. If you are accepting seed from the field, you don't have this option, but samples of seed from each grower should be identified so that when tests are conducted, you can evaluate the respective growers. If you are producing your own, seed samples from each load should be saved for spot checks and/or future reference if additional quality information is needed.

A systematic monitoring of seed as it passes through the conditioning plant is necessary. Samples collected periodically from different points in the conditioning line can often be used to identify where problems are occurring. The volume of samples need not be large. If problems arise, then sample frequency can be increased if necessary. Any profiles that you can develop on growers, production areas, or methods of handling, etc. can be useful to you in evaluating your program. Records can be extremely important to you in solving problems and evaluating your business.

A sound testing program is basic in a quality assurance program. Evaluation for mechanical damage is quite often a vital part of a program. Visual inspection of a sample may be all that is necessary. Seeds such as cotton may be evaluated as to the severity of the damage. The indoxyl acetate test for soybean, the fast green test for corn or other starchy grains are tests that will aid in evaluating mechanical damage.

The standard germination test is basic. There are certain minimum levels of germination that you will accept for marketable seed. If these standards aren't met, there is no need to proceed any further.

There are several other tests that may be useful to you in assuring the quality level you want. The tetrazolium test is fairly quick. Germination can be estimated as well as quality. It is particularly useful in problem solving. Such things as "hidden" mechanical damage, heat damage, acid burn in the case of cottonseed, insect damage, and possibly other things can be determined from a tetrazolium test.

The soil cold test is almost universally used by the better corn seed companies and may have application to other species.

Accelerated aging has several applications. It was developed to predict relative storability of seed lots. If you know that you will have to carry over some seed lots, you can select those that have the best potential of maintaining germination during the carryover period. With some detailed work, you probably can estimate absolute storability, i.e., about when a seed lot will begin to break in germination. In the case of soybeans stored here at Mississippi State University, we predicted which lots would sustain an acceptable level of germination through the planting season. Accelerated aging is being used as a vigor test in some labs.

Measuring leachate or conductivity test may also have some application. As seed deteriorate, the membranes lose their integrity, allowing cellular materials to "leak out" at a more rapid rate thus measuring conductivity or resistance of steep water gives an indication of seed quality.

Low temperature germination indicates the quality of cotton seed.

Seedling growth rate has some application. There are other tests that have specific application to one seed kind like the cutting test for estimating germination of cottonseed and free fat acidity. You must decide which of these tests you need in your quality assurance program and develop your program accordingly.

The Association of Official Seed Analysts has published a Vigor Testing Handbook. This publication contains the procedures of vigor tests that have been researched and are being used in the seed industry. These are available from the Secretary-Treasurer of AOSA.

INSECTS AND PESTS THAT AFFECT SEED QUALITY

John R. Pedersen[1]

Insects and other pests can have an adverse effect on seed quality after it has been harvested and while it is being stored and/or conditioned. The primary emphasis here is on insects and how they can affect seeds both directly and indirectly. Less emphasis will be placed on how rodents, birds, and microorganisms can affect seed quality. It has been said that the more you know about your enemy, the better you are able to combat him. It is with that approach that this subject is addressed.

Insects

General

Of over a million different species of insects that are present in our world, only a relatively small number have adapted themselves to living in the rather dry environment that we call seeds. The insects that we have to be concerned with in seeds, are the same as those in market grain storage. Some of these insects are internal-infesting insects that spend their developmental period inside individual seeds and others are external-infesting insects that develop totally on the outside of seeds. each of these kinds of insect can result in a different type of damage as far as seed quality is concerned.

Insects belong to a group of generally small animals called Arthropods. The insects, with a few exceptions, are smaller than the seeds they infest. They have an exoskeleton which give them certain characteristics that allows us to differentiate between these insects. The exoskeleton also gives them a certain amount of protection against the rather dry environment in which they live.

Insects don't arise by spontaneous generation, although it may seem that way sometimes. However, we must have a male and female insect that mate and then the female lays eggs. The insects that infest seeds generally lay a large number of eggs, in the range from 100 to over 400, with an average of about 200 eggs per female. The eggs are laid either into grain kernels or loosely among the kernels and hatch within a matter of a few days into a small form that is called a larva. The larva goes through a series of growth stages where it increases in size.

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It is in this stage that most of the direct damage occurs as a result of larval feeding. Generally, the larva goes through a series of four growth stages called instars that usually take about 20 to 24 days. Then the larva transforms in a pupa where the insect completely changes it appearance from that of a worm to that of the adult insect. It generally remains in this stage for about four to five days and then transforms into an adult. Within a matter of two to three days the adult is able to start mating and laying eggs again. This is a relatively short life cycle, approximately 30 days depending upon the conditions under which the insect develops.

The conditions needed are a favorable temperature, a favorable moisture content, and a suitable food material. Below 60°F we find that the temperature tends to restrict the multiplication of insects. Temperatures of 70 and 80°F seem to be the optimum and when we get to higher temperatures, 90°F and above, the numbers tend to drop off. Most of the lower temperature control is probably due to reduction in egg laying, whereas at the higher temperatures, probably due to the inability of insects to maintain their water balance in a relatively dry environment. In cereal grain seeds with less than 12 percent moisture content there is a rather dramatic reduction in the number of insects that will be produced. At 12, 13, and 14 percent moisture content, conditions are the most favorable as far as insect development. Above 14 percent there is less concern about insects and more about the microorganisms or molds that may attack cereal grain seeds.

Hypothetically, it has been calculated that starting out with just one pair of insects within a matter of about five months you could have well over a million insects just from that one pair. This, assuming that the female will lay 200 eggs, approximately 80 percent of the eggs will survive, and that it takes approximately a month to complete a life cycle. This should provide an idea of how rapidly a population of insects can multiply if something is not done about controlling it.

Internal Infesting Species

Weevils, borers, and the Angoumois grain moth comprise the internal infesting species. There are three very closely-related weevils that infest seeds, the rice weevil (*Sitophilus oryzae*), the maize weevil (*S. zeamais*), and the granary weevil (*S. granarius*). The grain weevils are characterized by having a long slender snout. There are other characteristics that are used to separate the various weevils but they will not be discussed here.

The weevils use the long snout to chew holes into seeds. After the female weevil has chewed a hole into the seed it turns around and inserts its ovipositor and lays an egg right inside the seed. The egg is covered with a small gelatinous plug to protect it and makes it virtually invisible to the naked eye. The egg hatches within a matter

of a few days into a larva and the larva, as indicated, goes through a series of growth stages, all on the inside of the seed. At each growth stage the larva forms a new exoskeleton and then casts off the old one, increasing in size at each stage. The weevils go through four of these growth stages, or larval instars. The larva is the stage that does all the feedling inside the seed. Still on the inside of the seed the larva transforms into a pupa, and takes on the characteristics of the adult. It emerges from the kernal by chewing its way out. It then goes on to set up this same cycle again. Under proper conditions for development, the rice weevil egg will hatch within 3-4 days. The larval period requires about 20-22 days; the pupa 3-4 days; and the adult before emerging about 3-4 days.

One thing that's important from the standpoint of seed quality is the fact that from one-third to more than one-half of the seed may be consumed in the development of weevils on the inside of a seed of wheat. The rice weevil is a relatively small insect and there are cases where we can actually find two individuals developing on the inside of a given seed, and in that case virtually all you have left is the pericarp and the embryo. Studies have been conducted indicating that where one insect develops in a wheat seed, 10 percent of those seeds will germinate. In other cases, none of the seeds germinated.

The maize weevil looks virtually the same as the rice weevil but is generally slightly larger in size. The names do not necessarily mean or indicate where the insect feeds exclusively. The weevils will cross-feed on a variety of types of seeds. The maize weevil has actually been found in acorns. It goes through the same kind of life cycle as the rice weevil. The third species, the granary weevil, is uniform in color and is not capable of flight. This is in contrast to the rice and maize weevils, that have four light spots on the wing covers and do have functional flight wings. The maize and granary weevil take slightly longer to complete their life cycles.

Another insect that develops inside the grain kernel and creates the same kind of damage by consuming the endosperm or the carbohydrate storage reserve is called the lesser grain borer (Rhyzopertha dominica). It's microscopic in size and about the same size as the rice weevil but it is cylindrical in shape, like a piece of pencil lead and does not have a long snout. The lesser grain borer goes through the same kind of life cycle as just described, however, the eggs are laid outside the seeds and the newly-hatched larva must chew its way into the seed. From that point, development occurs within the seed until the adult emerges. The adults also feed on seeds and are capable of penetrating various types of packaging material. Production of a large quantity of dust is another characteristic of the lesser grain borer. It produces a very distinctive odor which is probably carried through the dust that it generates; most of this is excrement. It's a very voracious feeder. As the larva develops, it feeds and consumes a large amount of carbohydrate material and then also as the adults feed they continue to consume seeds

and cause quite extensive damage. Another pest that is very closely associated with the lesser grain borer is the larger grain borer (Prostephanus truncatus). This has become a serious pest in some of the African countries and was said to have been imported from the United States. This is an insect that primarily attacks seeds that may be stored on the ear starting at one end of the cob and going right down through the embryo and then exiting at various points.

Indirect damage due to internal infesting insects. Development on the inside of the seed consumes a part of the seed so that it makes it a less valuable commodity as far as planting for production. But some of the indirect damage can be equally detrimental. The weevil can be used as an example. As the larva develops it feeds; as it feeds it is producing waste products. The cast skins that are left behind are food contaminants and from the standpoint of seeds are not important. More important from the standpoint of seeds is the fact that there is heat generated by the insects as they metabolize the carbohydrate material. As they feed, insects generate a certain amount of heat, a certain amount of moisture, and some carbon dioxide. That heat can accumulate in bulks of seeds because seeds are generally good insulators and a large enough population of insects developing in a quantity of seeds can create what is called a "hot spot" or a portion within that quantity of grain where the temperature increases. As the temperature increases, the insects don't like it, and tend to move out or migrate. That tends to spread an infestation and not only will this quantity of seed be damaged but will also spread the insects to other parts of the seed storage whether in sacks or bulk. Also, this "hot spot" by increasing the moisture content in this localized area can promote the development of microorganisms. They're very devastating as far as the embryos are concerned and can destroy the viability of the seed very rapidly. In addition, the hot air that is produced here tends to move upward and tends to carry warm moisture with it to the surface where we may have condensation of moisture onto the seeds at the surface or absorption in the seeds below the surface. This in turn will promote conditions that are favorable for the development of microorganisms.

Another insect that develops inside the grain kernels is the Angoumois grain moth (Sitotroga cerealella). Where seeds are stored in bulk its infestation is confined to the surface area. Because it is a moth and is very delicate it can't penetrate down into large bulks of seeds. This insect scatters its eggs over the surface of the seeds. The eggs hatch and the larvae chew their way into the seeds. From that point on their developmental cycle is within the seed. After the larva has gone through all the growth stages it transforms into a pupa, still on the inside of the seed. The adult moths don't have mouthparts with which to chew so it may be a mystery as to how they get out of the seed. Before it transforms into the pupa, the larva goes to the surface of the seed and makes a "window" for an escape hatch. It then transforms into the pupa and when the adult is ready to emerge all it has to do is push open the "window" and work its way out. It is then free and ready to

start mating and laying eggs again. The adult moths die within a matter of a few days. All the damage done by this insect is by the larva. Another thing that is important about the Angoumois grain moth is that in its diet it seems to have a need for the types of materials that are in the embryo. Whenever it feeds on a seed it consumes a certain amount of the embryo. The size of the seed pretty much determines the size of the adult insect. It's interesting too, that even though we have a small moth from a seed of millet, the size of the egg it lays is about the same size as the eggs layed by moths from maize. The moth from millet may produce just one egg but it's a good sized one. The Angoumois grain moth is one of the few insects that has the ability to penetrate paddy rice or rough rice. The outer hull of the rice kernel provides protection from many of the other insects. The Angoumois grain moth and other moths are probably more damaging to seeds where the seeds are stored for periods of time on the head because it exposes all of the kernels.

Beans are subject to infestation by insects known as bean or pea weevils belonging to the family Bruchidae. Some of these insects lay their eggs directly on the seeds and some infestation occurs in the field and is brought into storage. Bruchids develop on the inside of seeds and emerge in much the same way as the Angoumois grain moth, creating an escape hatch. The adult doesn't feed and most of the damage again is done by the larva as it develops. The bean seed, being a little bit larger, can tolerate a certain amount of insect damage. Where uninfested beans showed a 75 percent germination when only one insect developed, that percentage dropped to about 44 percent and as the number of insects increased to four, the germination of seeds went to 0. It's not uncommon to have more than one insect develop in bean seeds.

External infesting insects develop outside the seeds. The Indian meal moth (Plodia interpunctella) is another moth that many of you have probably seen. Again, the adult moth doesn't feed and dies in a relatively short period of time. It does lay eggs over the surface of bulk stored seeds or along seams of bags. When the eggs hatch, the larvae feed on the seeds. Their primary point of feeding is at the embryo. The larvae feed on the embryo first, and then they'll continue back into the endosperm portion of the seed. They do a very clean job of scalping out the embryo and leaving behind a seed which still has most of the endosperm present but can't be grown into a new plant. The Indian meal moth probably consumes 40 embryos per larvae as it develops and if you have a heavy infestation quite a few embryos can be destroyed in a relatively short period of time. When the larva is ready to transform into the adult, it migrates and comes out of the bulk or bagged seeds and looks for a place to pupate. Cracks and crevices along the doors or on the insides of storage facilities are good places for them to pupate; or along the areas where sacks may be stitched together. In addition to laying eggs over the surface of bulk stored seeds, a favorite place for laying eggs is along the folds in sacks. When the larva hatches it has direct access into the packaging material.

If a lot of dead moths are observed lying on the floor it doesn't necessarily mean that your control program has worked. It may mean that you have a pretty good-sized infestation and that these adults have just died and are lying there on the floor for you to sweep up. Remember that adult moths live only a matter of a few days to a few weeks and their only function is to mate and lay eggs.

Another of the external infesting insects that we find in cereal seeds are flour beetles, the Tribolium species. They prefer a diet of ground or cracked seeds rather than whole seeds but when forced they will live on whole seeds. On sound seeds, larvae and adults scalp off the embryo first and then feed back on other parts of the seed itself. But the more broken seeds you have the greater opportunity for this type of insect to develop. Again, its prime target as far as food materials it's feeding and developing in these seeds is the embryo and it doesn't take long for them to destroy quite a few seeds.

There are other insects such as the saw-toothed grain beetle (Oryzaephilus surinamensis) which gets its name from the six saw-tooth structures on each side of its body. Larvae and adults feed on the embryos and look for seeds where there may be cracks in the pericarp over the embryo. The flat grain beetles (Cryptolestes spp.) actually can complete their development living right under the embryo. A crack in the pericarp or any kind of break allows the egg to be laid there, or a small larvae to penetrate, and then it stays right inside the seed and its prime food is the embryo of the seed.

The Dermestids, primarily the genus Trogoderma, feed on seeds and it's the larvae again that do the most damage feeding on the embryos. The adults are relatively short lived, but the larvae are particularly hazardous because when food is not available they can remain dormant for long periods of time. When fresh seeds are available the larvae again become active and it's the embryo they intend to go for.

Some of you may see a cadelle (Tenebroides mauritanicus) occasionally, especially if you have wooden types of storage. The larva of this insect feeds on the embryo but it also has the ability to feed on the storage structures. It will tunnel into wood and at times infestations can become so heavy that they weaken the structure itself. In addition to providing a place where the larvae can develop, tunnelling in wood provides a place where dust can accumulate, mold spores can develop, other insects can receive a certain amount of protection from pest control measures that might be applied such as treatment with insecticides or fumigants. the cadelle is an insect that has the capability of living through a winter and some pretty cold temperatures.

Another type of damaging organism that is even smaller than the insects is mites. They are more closely related to spiders and ticks. They also have as their prime target in feedling, the embryos of seeds.

In general, the external infesting insects--the grain beetles, the flour beetles, the Indian meal moth--are probably more damaging on seeds which have an exposed or a relatively exposed embryo in contrast to those seeds such as barley and oats which have more protection.

Rodents

General

Rodents can cause a direct reduction in seed quality and can also be a source of concern to seedsmen in a variety of other ways. Like many of the insects, rodents seem to have a preference for the embryo of cereal grain seeds. This is particularly true of corn where the embryo with part of the endosperm is consumed first. With the smaller grains such as wheat and sorghum often the entire seed is consumed.

In addition to actual destruction of seeds, rodents can be damaging from the standpoint of container and facility damage. Sacks (jute, paper, and polyethylene) can be chewed by rodents with subsequent spillage and loss. There is also the problem of appearance of packaging on customer acceptance of the product. A rodent chewed or contaminated package is aesthetically less acceptable than a sound package. Rodent chewed bags which resulted in spillage from the bottom bags of a stack caused a stack collapse with resultant structure damage to the warehouse wall and door.

Because of a "need" to keep incisor teeth worn, rodents chew on solid objects such as wood, mortar, and other construction materials. The damage created can provide access for additional rodents; inaccessible harborages for both rodents and insects; and in some instances fires have been attributed to rodent chewing of electrical wiring.

Rodents are carriers of diseases which can be spread directly in excreta and urine or indirectly through ectoparasites. Although the diseases carried by rodents will not affect seed quality, if rodents are allowed to exist in seed conditioning and warehousing situations the potential for employee health problems exists.

The Rodents

There are three species of rodents which have adapted themselves to living in close association with human populations--the Norway rat (*Rattus norvegicus*), the roof or black rat (*Rattus rattus*), and the house mouse (*Mus musculus*). There are field rodents which may on

occasion enter structures but they are considered incidental pests when compared to the three commensal rodents indicated above.

The rats can be distinguished from one another by certain body characteristics and behavior. The Norway rat is an aggressive robust animal. It may weigh as much as one pound when full grown and may measure about 18 inches from nose to tip of tail. A blunt nose and small eyes and ears in relation to head size together with a relatively stout, short tail (shorter than head and body length) characterize Rattus norvegicus. The roof or black rat is smaller (about 3/4 pound) and has a pointed nose and large eyes and ears in relation to head size. The tail is longer than the head and body combined. As the name implies, the roof rat prefers an elevated location, crawling in overhead areas of structures whereas the Norway rat is a burrowing rodent that tunnels and lives in the ground, moving into structures to feed. In the U.S., the potential to encounter the Norway rat exists across the entire country especially in urban areas; the roof rat is a more tropical type of rodent and more likely to be found along the west coast and Gulf and Southeast Atlantic coastal areas.

Mus musculus, the common house mouse, is found virtually everywhere in the world. It is a very small rodent somewhat deceiving in its appearance. the grey fur that covers the mouse makes it look much larger than actual. Small mice can enter openings slightly larger than 1/4 inch diameter. Mice generally weigh about an ounce when full grown and measure about 6 1/2 inches in length from nose to tip of tail.

The rodents are similar in that all are nocturnal, prefer hidden situations, have good senses of hearing and smell, have poor eyesight, can swim, can climb rough surfaces, and live, on the average, about one year. Rodents differ in their potential for reproduction with the rats producing about equal numbers per female with mice producing about twice as many per female per year. Rats also differ from mice in feeding and behavior. Whereas rats are very cautious in their movement and suspicious of new or a changed environment, mice are curious and readily explore new situations. feeding habits of rats reflect this also. Foods used in baiting programs may not be taken immediately but once accepted by rats, will be consumed in quantity. Mice are curious and will readily try new foods making use of a variety of baits (gum drops, peanut butter, bacon grease, etc.) in trapping quite effective. Liquid baits may work best for rats because of their need for a source of water; mice can metabolize the moisture they need from foods they consume.

Since rodents are nocturnal and prefer a concealed environment, they may not be seen physically. We rely heavily on seeing evidence of their activities to detect their presence. Droppings (excreta pellets) are easily seen and identified; and urine can be detected on packages using a "black light" (ultra-violet light). Chewing on packages and structures can also be identified easily. Since rats, especially, move

over set pathways ("runs"), they can be detected by tracks, beaten paths, or body stains.

Birds

In seed storage, birds are more of a nuisance than a factor in the loss or reduction of seed quality. Cereal grains will be consumed when they are exposed as spillage around storage or conditioning facilities. But from the standpoint of quality, birds probably contaminate much more seed than they consume.

Birds roosting on the roof of a plant or storage facility or accumulations of bird droppings (excrement) on the exterior of facilities or on seed packages are an indication to customers of poor management.

An incidental but interesting association exists between bird nest and seed infesting insects. Certain species of Trogoderma have been found infesting bird nests, feeding on feathers and other nest materials and have subsequently infested cereal grains.

The two species of birds that are most likely to be pests at seed storage and conditioning plants are the English or House Sparrow (Passer domesticus) and the feral pigeon (Colombia livia).

When food and other conditions are favorable, sparrows can be expected to produce about 35 young per female where as pigeons will produce about 10 per female per year.

The sparrow is a particular nuisance in that it can enter very small openings and will readily nest in any small opening or space where a few pieces of grass or twigs can be forced. Once inside a warehouse, sparrows are quite difficult to remove and a considerable amount of product can be defaced with droppings within a relatively short time.

Pigeons prefer to roost in large numbers generally on the roofs or window ledges near areas where spillage occurs and accumulate. This is particularly true along rail and/or truck loading areas. Where pigeons may roost repeatedly in a confirmed area, the accumulation of excrement could provide a source of Histoplasma capsulatum, the causal organism of histoplasmosis.

Pest Control

An integrated approach is suggested for pest control in maintaining seed quality. Four basic groups of control methods are proposed: inspection, housekeeping, physical and mechanical, and chemical methods.

Inspections are used to detect potential or existing pest problems so that corrective action can be taken. Inspections can also be used to monitor an existing pest control program to see whether it is functioning according to expectations.

Housekeeping, simply stated, is cleanliness and orderliness and involves not only the interior of the storage and conditioning facility but also the plant perimeter and exterior. Orderliness in storage of bagged materials is an important adjunct to facilitating inspections, rodent control, and chemical control applications.

Physical and mechanical methods of control include temperature and moisture alteration of bulk seed stocks as well as particle size and density separations. Rodent and bird proofing of storage and conditioning facilities falls within this category of control as do traps and other mechanical pest control devices.

Chemical methods include contact insecticides, fumigants, rodenticides, and avicides. Only certain pesticides are approved for control of the pests discussed. Since by-products from seed conditioning plants may eventually be channeled to human or animal food uses, it is important that only those chemicals approved for food plant and storage facilities be used prior to treating and packaging cereal grains for seed purposes.

The integrated use of the methods mentioned with the emphasis on preventive pest control methods can reduce the potential for reduction in seed quality.

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Basic Operations in Seed Conditioning
"Pre-Conditioning"

Howard C. Potts[1]

Seed conditioning is the act of preparing harvested seed for planting. The purposes of seed conditioning are to improve the physical purity, germination level, appearance, planting characteristics; to apply seed treatment materials and package the conditioned seed. In the modern context, seed conditioning is done mechanically.

Seed conditioning may be sub-divided into five operational phases based upon differences in the physical characteristics of harvested seed of different kinds and varieties, the unit value of the seed conditioned and the seeding methods used. Sequentially the five phases are pre-conditioning, basic cleaning, upgrading and finishing, seed treatment and packaging. A given lot of harvested seed may be subjected to one or several of these operational phases. Only the basic cleaning phase is required by all seed lots which move through commercial channels; the need for additional conditioning is determined on a lot by lot basis.

Seed of many, but not all, kinds may require some additional preparation after they have been harvested and placed in bulk but before they can be cleaned, graded or treated effectively. For example; maize must be shelled from the cob; "beards" (awns) must be removed from some varieties of barley, oats and grass seed; before the quality characteristics of the seed lot can be improved significantly. Those activities necessary to prepare a seed lot for basic cleaning are referred to as pre-conditioning the seed.

Pre-conditioning is usually a high volume operation done primarily to increase the effectiveness and efficiency of subsequent operational phases. Seed lots are pre-conditioned to change the physical characteristics of the entire seed lot and/or the individual seed in the lot. The physical characteristics of the seed lot are changed by removal of materials much larger, smaller or lighter than the good seed in the lot. Characteristics of individual seed may be altered by removal of appendages or coverings, separation of seed clusters into individual seed, removal of the seed from other plant parts, and/or scarifying the seed coats to make them permeable to water.

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[1]Professor, Seed Technology Laboratory, MSU.

The specific operations included in pre-conditioning seed are as follow: scalping, shelling, debearding and hulling-scarifying.[2] The kind and physical condition of the harvested seed determines which, if any, of the pre-conditioning operations may be necessary and, therefore, the equipment necessary.

Scalping (Pre-cleaning)

Scalping is generally considered to be the removal of those materials larger in size than the bulk of the seed mass. However, because of the availability of a wide assortment of equipment, the "scalping" operation may include removal of the very small materials (grading) and/or materials significantly lighter than the seed mass (fanning). The basic purposes of scalping operations are to improve the flow characteristics of the seed mass and increase the efficiency of the subsequent cleaning and conveying operations. Figure 1 depicts samples typical of rice before and after scalping and the advantage of scalping - increased capacity of the basic cleaner.

The maximum benefits from scalping operations are received when they are done as the seed are received. The machine selected should have a capacity equal to that of the receiving elevator. Scalping the seed mass before conveying into bulk storage and/or drying bins contributes to insect and storage mold control, reduces the resistance of the seed mass to air flow, and increases the drying rate while reducing power and fuel consumption.

The type scalper most often used in the seed industry are the screen scalpers similar to those shown in Figure 2. These scalpers are available in one, two and three screen models, with or without air aspiration systems and in a range of capacities. The more sophisticated models permit removal of materials larger, smaller and lighter than the seed mass. Reel type-aspirating scalpers (Figure 3) are effective when it is only necessary to remove materials much larger (straw or pods) and lighter than the seed mass in crops such as rice, oats or wheat. "In-line aspirators" and "single-reel circular screen scalpers" are effective for removing dust and light materials or sticks and straw, respectively, during receiving operations.

Shelling Corn

Most seed corn is delivered to the conditioning plant on the ear and, therefore, must be shelled before the seed can be cleaned (Figure 4). Because much of the mechanical injury to seed corn occurs during shelling, very special attention must be given to this pre-conditioning operation.

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[2]Seed drying is included as a part of the pre-conditioning phase by some but is not included in this discussion.

Figure 1. Combine-run rice seed (above) the same seed after scalping (middle). Rice seed after cleaning with an air-screen cleaner (below). Note the influence of scalping on the cleaning capacity.

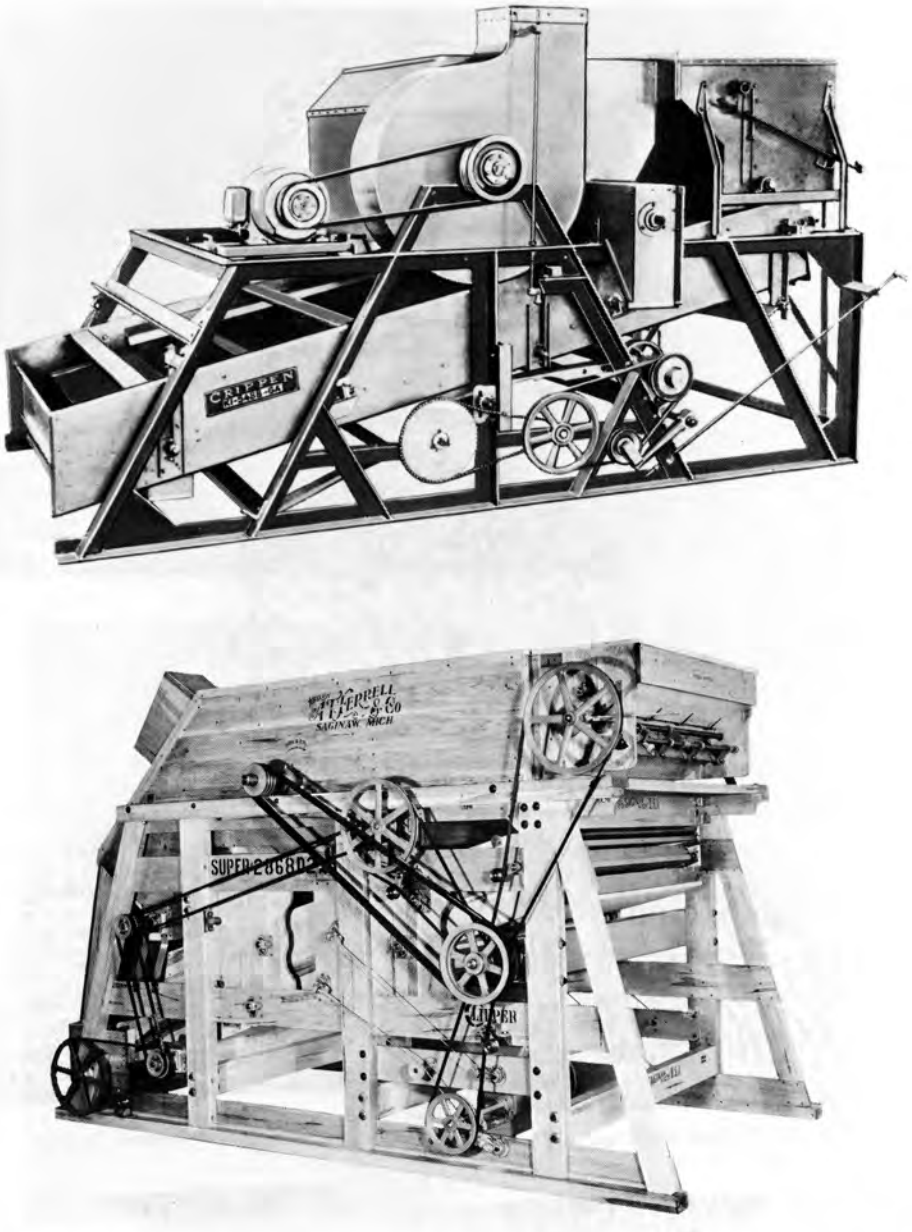
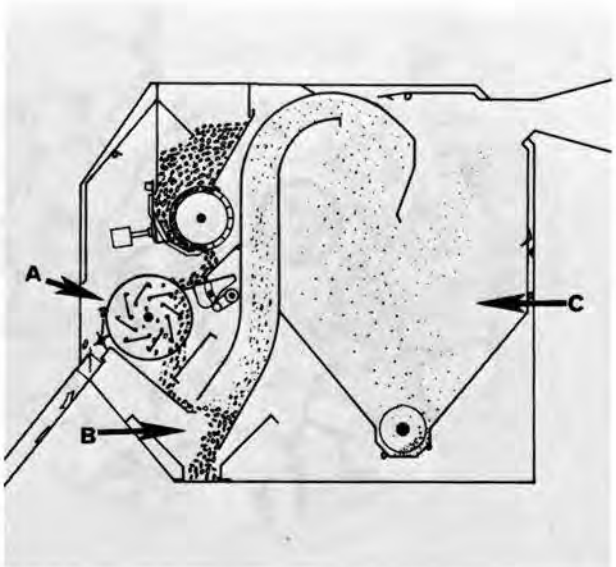


Figure 2. Flat screen scalpers. A single screen scalper with an upper air system (above). A two screen scalper with upper and lower air system (below).



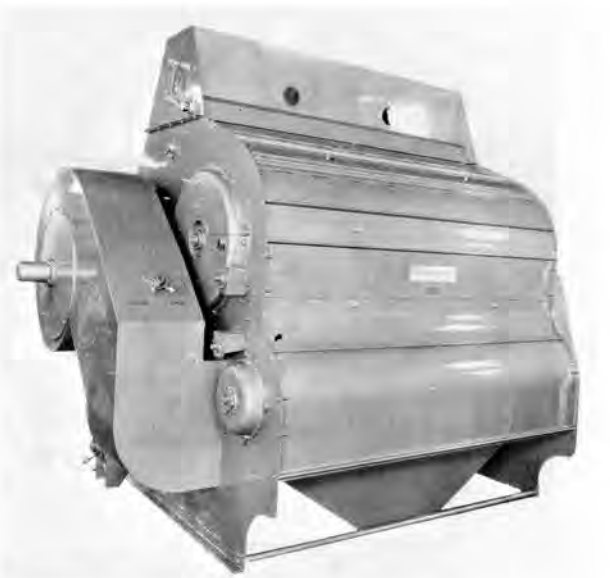


Figure 3. Reel-type scalping aspirator. Schematic flow diagram A-scalping reel, B-aspiration chamber, C-settling chamber (above). A commercial model (below).

Figure 4. Seed corn as discharged from the sheller (above) note mechanical injury to kernels circled. Cleaned, size graded seed corn (below).

Regardless of the sheller used, it is necessary that the "caps" of most seed impact with the bare metal "lugs" inside the sheller and some damage will occur. Damage can be minimized by operating the sheller at the minimum speed for the capacity needed; keeping the shelling unit full at all times, and shelling when the moisture content is below 20 % but above 13%. Based upon the observation that, "used shellers caused less damage than new ones", some corn seed conditioners have recommend filing down the sharp edges of the lugs on new shellers before initial use.

Most corn shellers have both a sheller and a screen and/or aspiration system which separates a major portion of the cobs from the shelled seed (Figure 5). Nevertheless, if the shelled seed are to be dried or placed into bulk storage it is highly desirable to further pre-condition the seed with an aspirating scalper to remove the light materials (bees wings) and small cob particles.

Debearding

Some seed have nat ural appendages attached, are not threshed free from other plant parts or remain in clusters after mechanical threshing. The presence of awns, glumes, seed clusters, etc.interferes with seed flow characteristics, separation efficiency and appearance of the cleaned seed.

The debearder is designed to reduce or eliminate problems such as those indicated above. The sequence of samples shown in Figure 6 depicts combine run barley before and after passing through a debearder and the appearance of the clean seed which were or were not debearded. Not indicated is the fact that the clean, debearded seed were higher in test weight than the non-debearded seed.

Seed fed into a debearder are vigorously agitated and rubbed together between sets of rotating and stationary beater bars (Figure 7A). This rubbing action completes threshing and breaks most appendages which project from the main seed unit. Seed moisture content should be below 13% prior to bedearding.

Most debearders are equipped with both a variable speed drive and a weight mechanism on the discharge gate. The desired debearding action is accomplished by controlling the rate of feed, rotation speed of the beater bars and the force required to open the discharge gate. The rotation speed and weight controls should be adjusted to minimize mechanical injury while still removing the undesired appendages from the good seed. The good seed and materials removed must then be separated during subsequent cleaning operations.

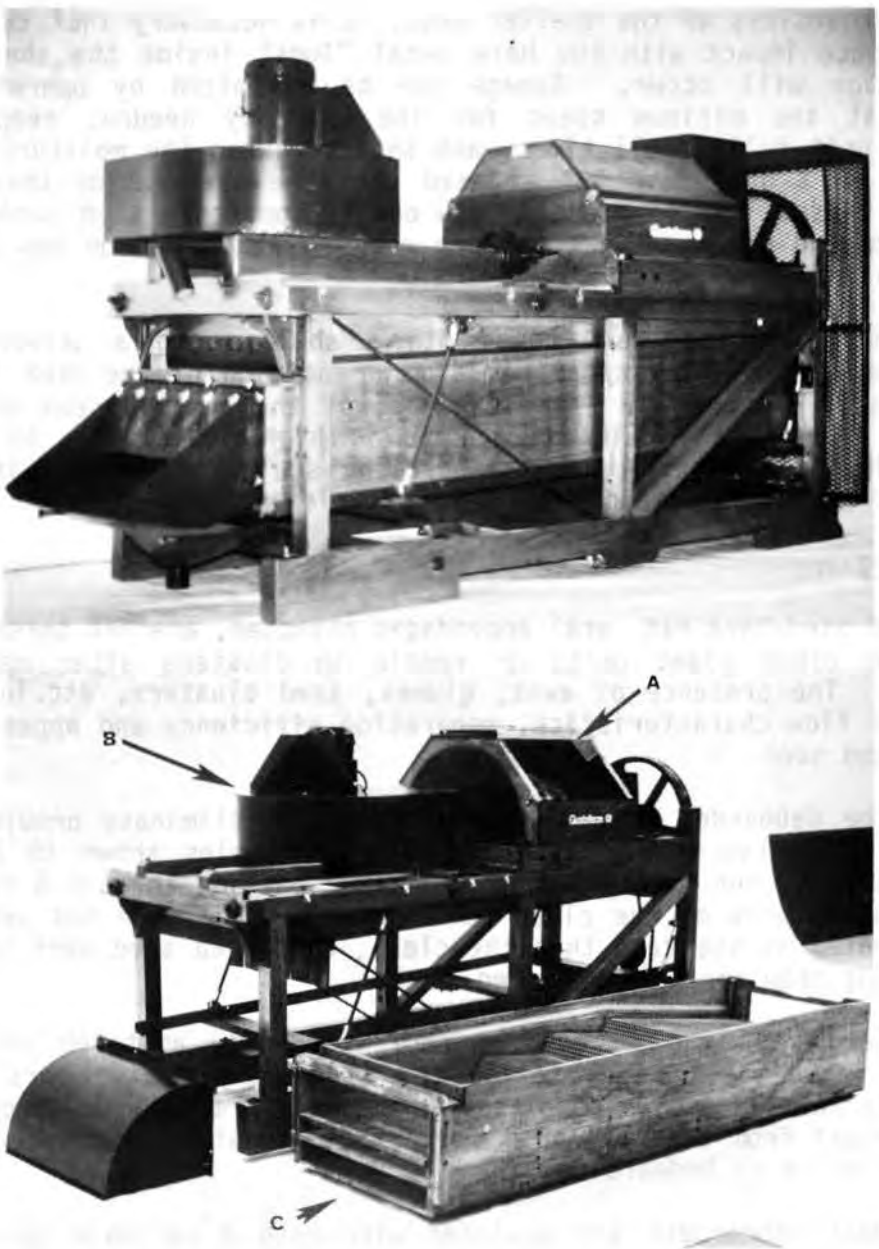


Figure 5. Corn sheller. Disassembled sheller with major components identified (above). A-shelling chamber, B-aspiration fan, C-screening mechanism. Commercial model of an assembled corn sheller.

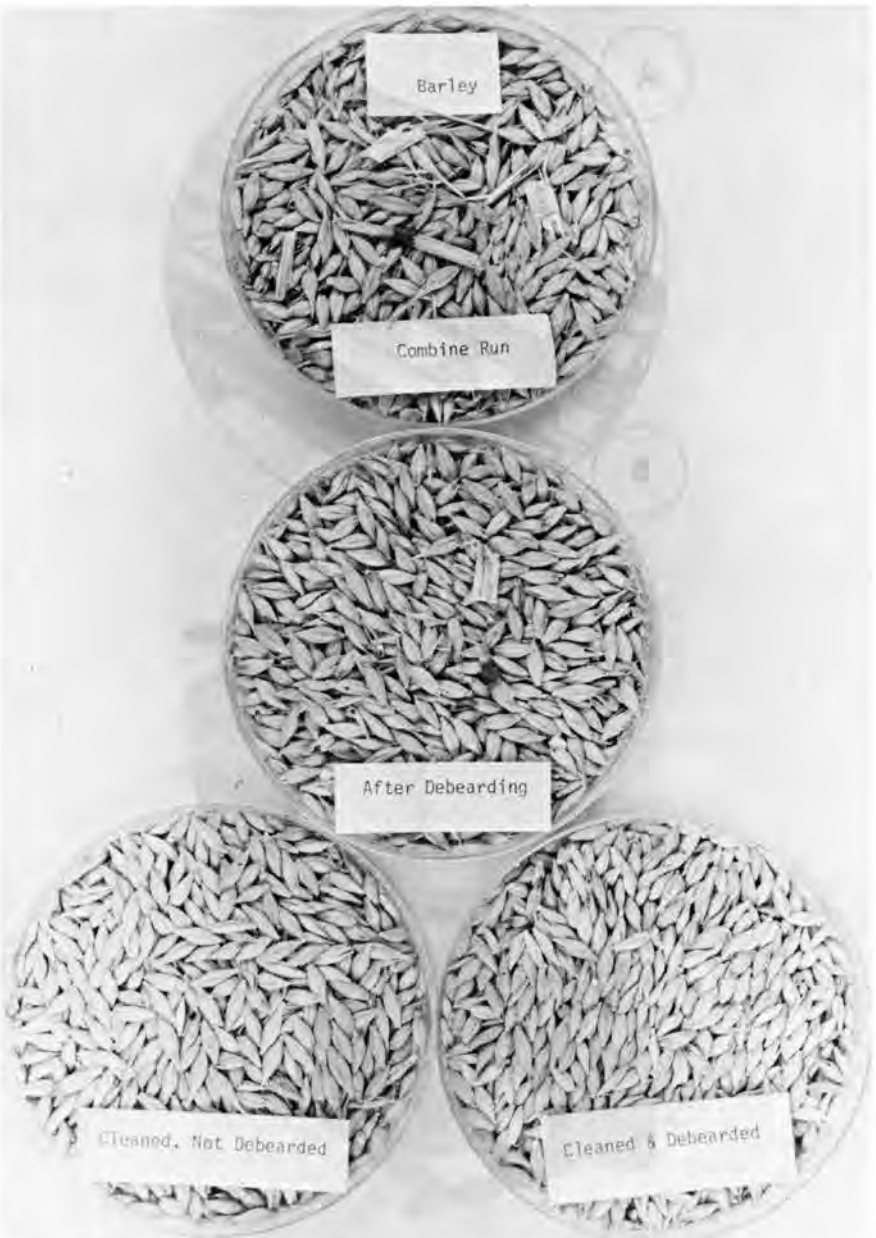


Figure 6. Barley seed. Combine-run seed (above). Seed after debearding (middle). Clean seed from lots that were not and were debearded (below).

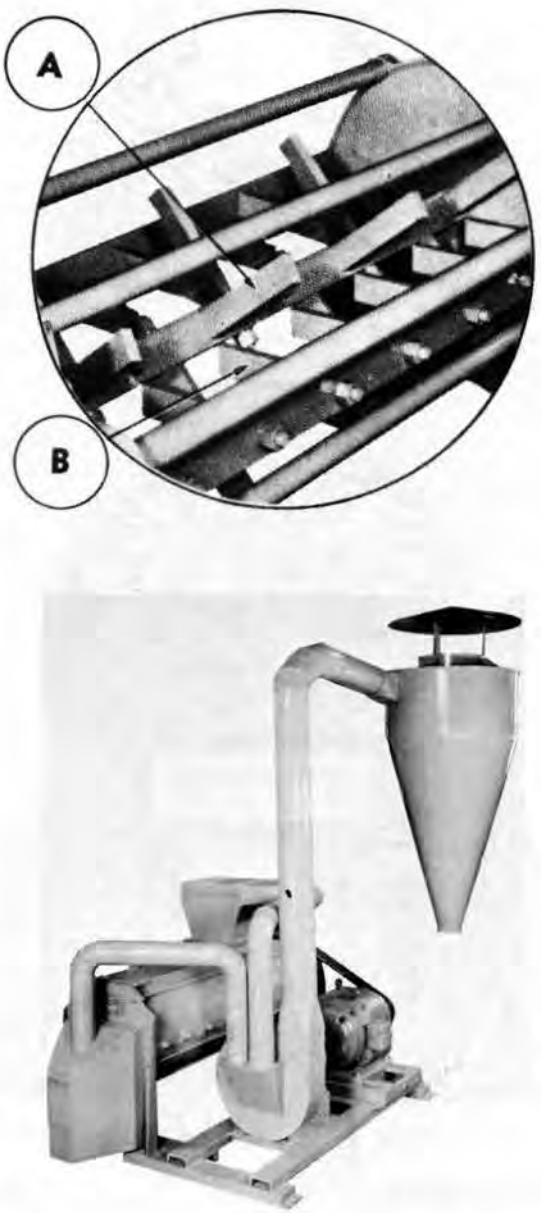


Figure 7. Debearder. Cut-away view showing (A) rotating and (B) stationary beater arms inside the debearder (above). Commercial debearder with dust aspiration system attached.

Hulling and Scarifying

Hulling; removal of the pods or "hulls" not removed during threshing, and scarifying; mechanically scratching the seed coat to make it permeable to water, is accomplished with a huller-scarifier. Hulling and scarifying can be different operations. It may be necessary to hull or scarify seed which are not threshed free of natural coverings and/or have a hard seed content in excess of 10-15% after threshing. Hulling/scarifying is primarily for seed of the small-seeded legumes; such as alfalfa, lespedeza, red clover, arrowleaf clover, etc., but is also used to decorticote seed such as sugar beet, dill, and carroway seed.

Hulling a seed changes its physical characteristics. When compared with an unhulled seed, hulled seed are smaller and have a higher weight per bushel. Hulled seed also have better flow characteristics than unhulled seed and, after cleaning, have a better appearance. There is both a weight and volume loss when seed are hulled; however, the overall quality of the cleaned seed is usually higher because immature and insect damaged seed can be removed more easily from hulled seed (Figure 8). One disadvantage of hulling occurs when contaminating weed seed present are smaller than the unhulled seed but similar in size to the hulled seed. Thus, a careful examination of the seed lot is necessary to determine whether the seed should be cleaned, then hulled and recleaned or simply hulled then cleaned.

Some lots of red, arrowleaf and subterraenean clover and hardseeded varieties of common vetch seed have as high as 50-70% hard seed after mechanical threshing even though the seed are threshed free from their pods and may not require hulling. Many other small-seeded legume seed may have more than 10% hard seed after threshing and cleaning. Seed lots which contain more than 10-15% hard seed should be scarified to permit rapid, uniform, stand establishment when planted. Unlike hulling, scarification does not change the physical characteristics of a hulled seed since, when done correctly the seed coat is only scratched, not broken. Conditioning personnel must be aware that scarification is controlled mechanical injury.

The samples shown in Figure 9 permit a comparison of the seed of arrowleaf clover which are not scarified and those that were scarified before cleaning.

All huller-scarifier machines utilize the same general principles to accomplish the job. They "throw" the seed at an angle against an abrasive surface. The force used to throw the seed and the surface against which they are thrown determines whether the seed are hulled, scarified, hulled and scarified or broken into pieces (Figure 10).

Whether hulling or scarifying, the seed moisture content and the quantity of cushioning material in each seed lot are the most important characteristics of the seed that influence machine operation. For

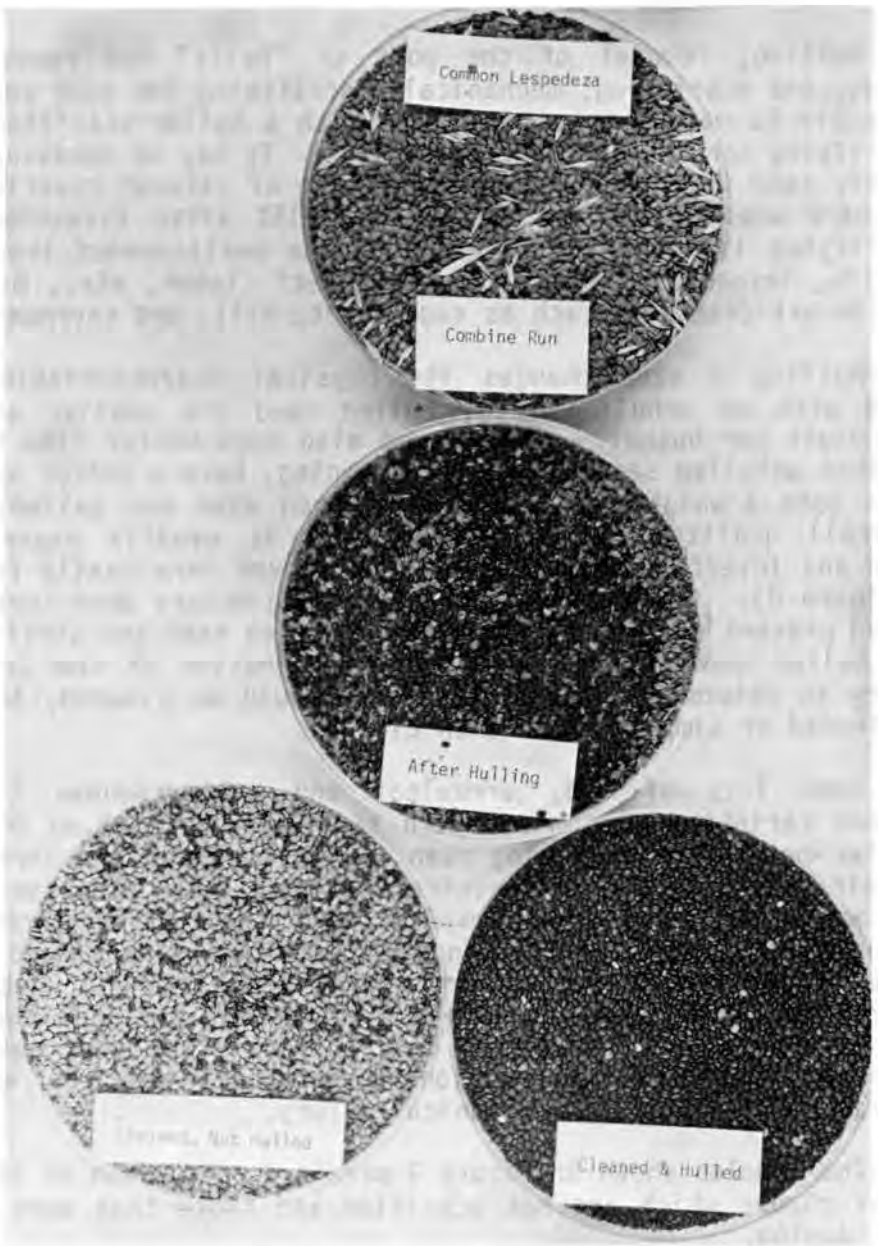


Figure 8. Common lespedeza seed. Combine-run seed (above). Hulled seed as discharged from a huller/scarifier (middle). Cleaned unhulled and hulled seed (below).

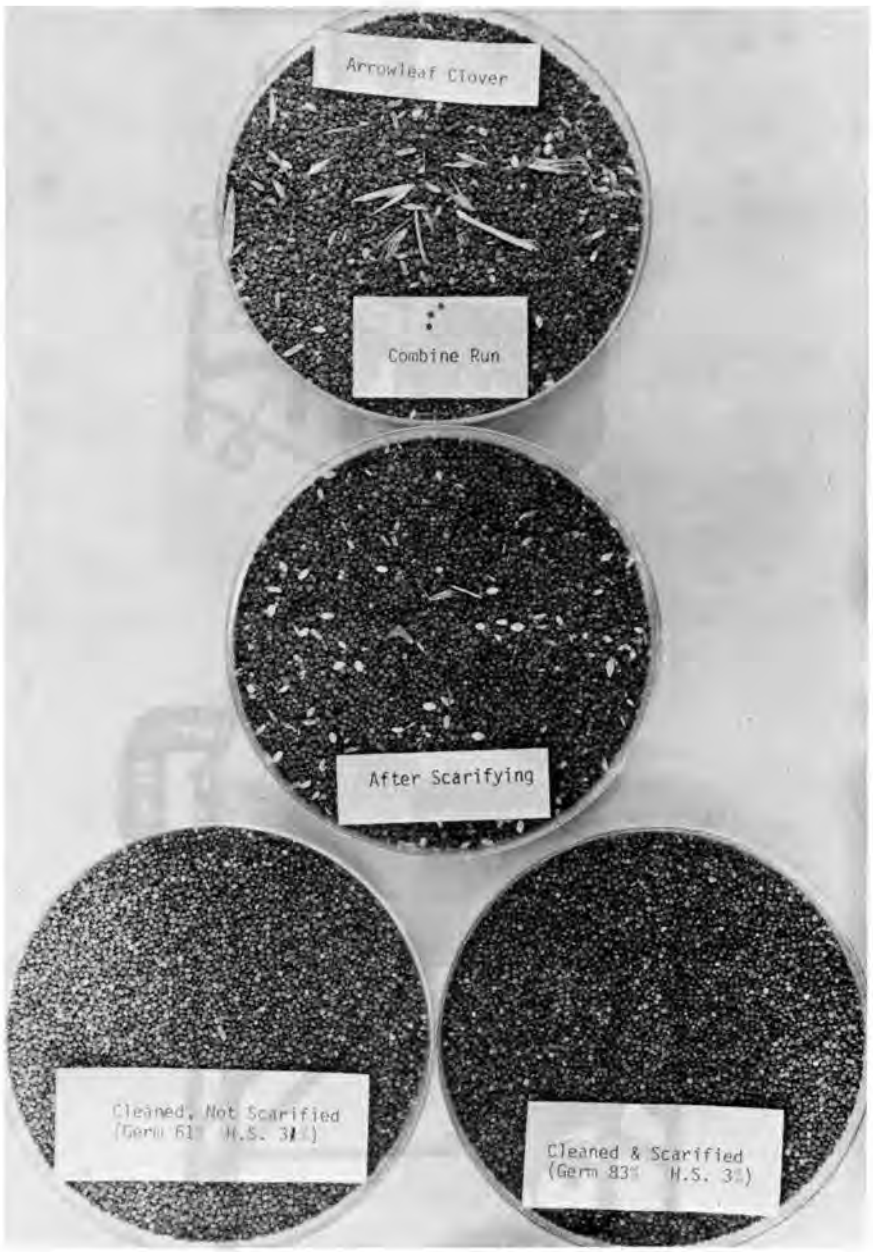
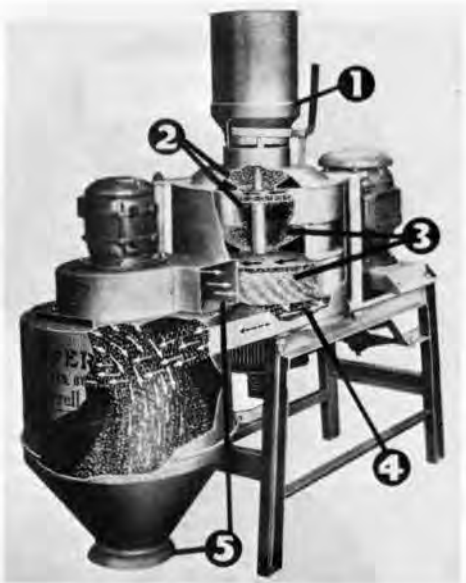


Figure 9. **Arrowleaf clover seed. Combine-run seed (above). Scarified seed as discharged from a huller/scarifier (middle). Cleaned seed which were not and were scarified. Note the differences in germination and hard seed contents.**



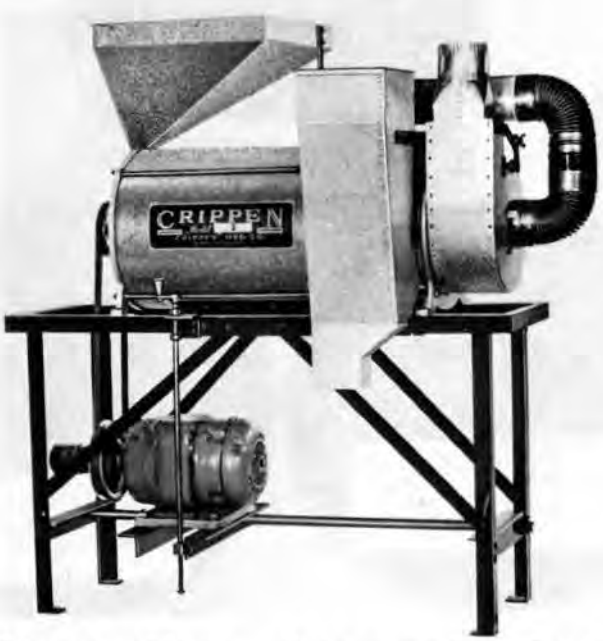


Figure 10. Huller scarifiers. Cut-away view of one commercial machine showing (1) feed mechanism (2) seed distribution (throwing) mechanism (3) abrasive surface (4) huller/scarified seed (5) aspiration system (above). Exterior view of another commercial huller-scarifier (below).

example, seed and plant materials are more resilient (tougher) at 14% moisture than at 10%. In a similar fashion, plant materials, such as hulls and stems, have a cushioning effect. For these reasons it is necessary to increase the speed of impact as the moisture and/or inert matter content of the lot increases.

The abrasive surface, feed rate and rotation speed of the seed distributing mechanism are the three operational controls common to all huller-scarifier machines. The abrasive surfaces used may be either "hard rubber" (urethane), carborundum or metal. The abrasive surfaces in all machines can be changed. When hulling, the less abrasive, hard rubber surface is recommended. When hulling and scarifying or only scarifying the carborundum or metal surface are usually necessary to achieve the desired results.

All scarifiers have a feed control mechanism. A uniform rate of feed is very important to obtain uniformity in hulling and scarifying operations. For this reason, most seed should be scalped before being fed into the machine. Surging of the feed rate can result in either excessive abrasion when the rate of feed slows or incomplete hulling or scarification when the feed rate increases from that desired.

Possibly the most important adjustment on a huller-scarifier is the speed of the seed distributing mechanism. The force at which the seed are thrown against the abrasive surface is controlled by movement of a variable speed pully which permits the operator to select from a wide range of speeds. The faster the rotation of the distributing mechanism the greater the impact force of the seed.

In summary, lots of field run seed which have high percentages of inert matter, are not completely threshed, or have a hard seed content exceeding 10-15% should be pre-conditioned before being cleaned. Properly done, pre-conditioning reduces drying time and costs, increases the capacity and efficiency of subsequent cleaning equipment, improves germination percentages and planting characteristics and can greatly improve the physical appearance of the cleaned seed. On the other hand; shellers, debearders and huller-scarifiers have the potential for causing high levels of mechanical damage to seed, and therefore, caution must be exercised when they are used.

SEED CONVEYORS-COMPARISON & CONTRASTS

W. H. (Bill) Wallace[1]

What is conveying! Two of the definitions given by Webster are "to bear from one place to another", and "to move in a continuous stream or mass".

When I think of conveying in a seed conditioning plant, it means anytime material is moved form one point to another. This applies to conveying horizontally, vertically or inclined, as well as by gravity to or from bins or through spouting.

Two prime problems are associated with the conveying of seed.

1. Seed Mixture
2. Seed Damage

When conveying seed ahead of any conditioning system, some mixing of physically dissimilar commodities may be tolerated because the conditioning equipment can make the necessary separation. Examples of mechanical mixing could be wheat in soybeans, clover in wheat, or very light seed mixed with heavy seed.

When conveying cleaned seed, mixing cannot be tolerated. To avoid mechanical mixing, we should use either self cleaning conveying systems or clean-out features must be designed into the plant equipment. Down time for clean-up between lots or varities is costly to production and manpower should be kept to a minimum.

Seed damage in seed conditioning plants should not be tolerated.

All who are in the seed conditioning business must remember that a "Seed" is a living organism. When seed damage occurs it is detrimental, regardless or where in the conditioning system. Seed damage may show up in one or more ways, for example:

1. Destroy germination
2. Splitting or chipping

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[1]Vice-President-Marketing, Blount/Ferrell-Ross, Bluffton, IN.

3. Loosening or skinning of seed coat

4. Dehulling

Once the seed is damaged, nothing can be done but to try to remove as much as possible, which results in loss. There is no point in throwing away precious seed revenues because our equipment damaged the seed. Moving equipment is not the only cause of damage. Too often the most unexpected places within a plant can be causing seed injury. Offsetting joints of spouting, unlined elbows, transitions, rough bin surfaces and unusual impact points.

In selecting conveyors to convey seed, care must be taken to ensure minimal damage, economical cost, ease of clean out and that it will not cause mixing.

Several factors should be considered in selecting a conveying system. The equipment must be adaptable to the following:

1. Movement - vertical, horizontal, incline or combination
2. Product - heavy, light, trashy, or bulky
3. Multiple feed points, single discharge
4. Multiple feed points, multiple discharges
5. Single feed point, single outlet
6. Single feed point, multiple outlets
7. Dust or water tight
8. Accessible for maintenance
9. Prevention of plugging
10. Mixing characteristics
11. Damage characteristics
12. Capacity needs

These are not all of the factors, a notable exception being Price. It would be ideal to disregard price, but, realistically, most decisions are made in the light of price - thus the comprise. The trick is to get the maximum number of factors covered.

The basic categories of conveyors are:

1. Bucket elevators - centrifugal type
2. Bucket elevators - continuous type
3. Screw conveyors
4. Belt conveyors - pan and trough - tube
5. Vibrating conveyors
6. Drag Flight conveyors
   a. Standard
   b. Mass flow
7. Pneumatic conveyors
   a. Positive
   b. Negative
8. Gravity spouting

Each basic category could take a session to go into the design and uses. But, time will not allow, so let's briefly make "Comparisons and Contrasts" of each type of conveyor as listed.

Bucket Elevators

Bucket elevators are manufactured in two basic types. Centrifugal discharge, and gravity discharge.

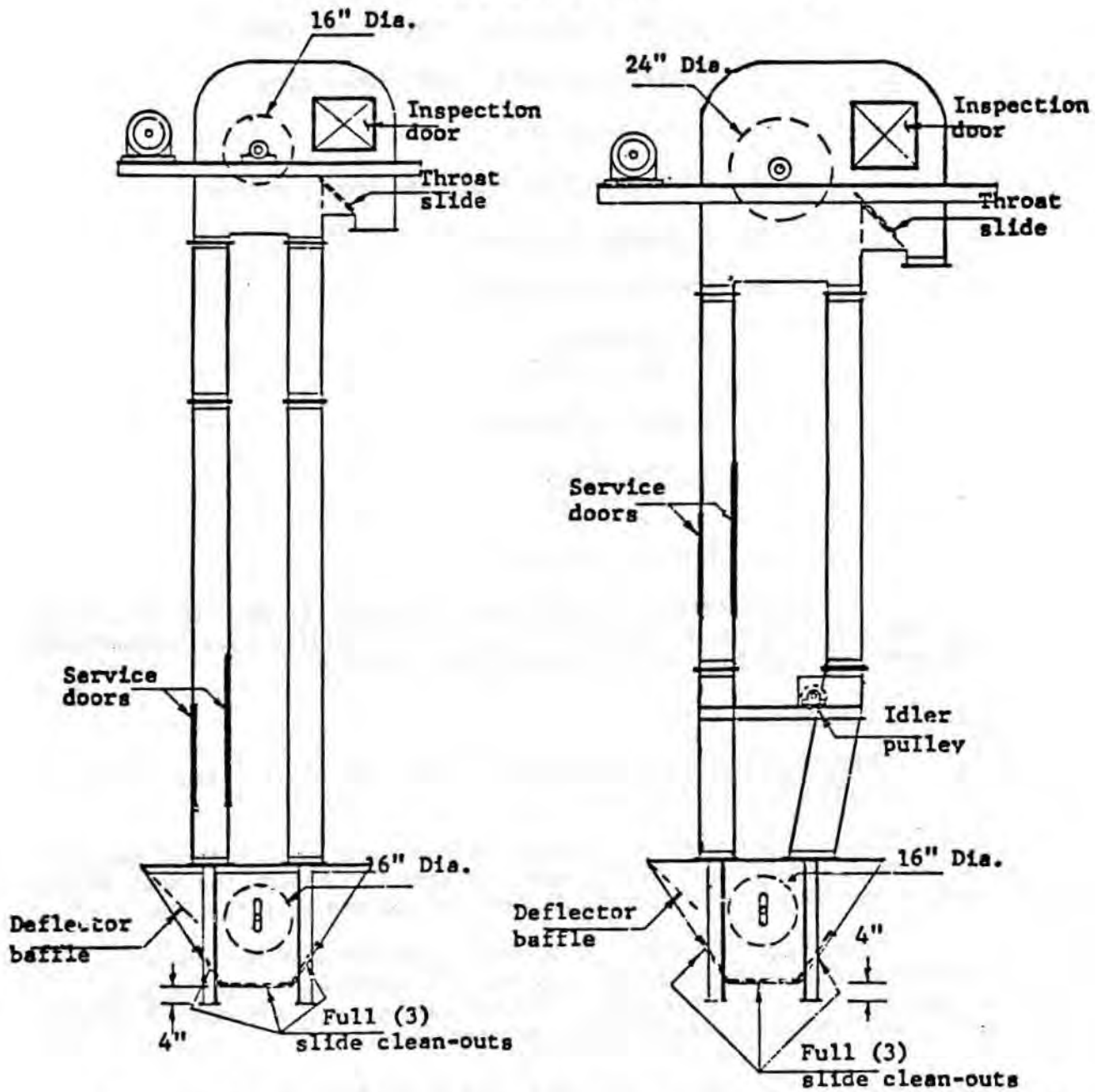
Centrifugal type as illustrated in Figure No. 1 without question is the most widely used in the seed industry. Although the most widely used it is the most misunderstood piece of equipment in the Seed Plant.

There are hundreds of bucket elevator manufacturers in the United States. Unfortunately very few are designed to handle Seed. For a centrigual bucket elevator to handle seed with a minimum of damaged seed, several design factors must be considered.

1. Select size and type of bucket and spacing.
2. Select diameter head pulley consistent with power applied, bucket size, F.P.M. travel most adaptable to product handled.
3. Select proper head design to assure good discharge and clearance for good flow of material.

FIGURE #1

"A" BELT & BUCKET ELEVATOR "B"



(A) Unit with head & boot pulley same size. This often done on elevators of smaller size or where height is not excessive.

(B) Unit with larger head pulley than boot. Preferred for permitting use of lower boot inlets, better cup filling & less material left in boot cavity. Head pulley size determined by required lift load and proper pulley and belt contact for horsepower employed.

4. Select proper boot design to allow proper filling of buckets, and easy clean-out.

5. Select inside leg clearances for safe operation.

All of these features are designed into a high quality elevator. Light duty economy elevators are built with short cuts to proper design and unfortunately it is the user who must live with the deficiencies.

Basically, bucket elevators of centrifugal design involve head and boot pulleys over which belting travels and onto which buckets are attached. Material picked up by buckets pass over the head pulley. The material is directed to the elevator throat discharge chute. The capacity of the system is solely related to the quantity of the material, usually referred to as cubic feet or bushels per running foot of belt. Running feet refers to speed at which belt travels over surface of head pulley.

We refer to two very different designs. Both are rated at about the same capacity, yet bring to focus some rather interesting evaluations. The illustrations on Figure No. 2 shows how a slower speed, large head pulley, and a high speed, small head pulley elevator may be rated at about the same capacity. There are other factors to be considered. The high centrifugal force caused by buckets passing over a small head pulley will account for high impact force. Additional negative effects occur in the boot because buckets will not fill properly until the mass of material builds up several feet in the up leg. High speed boots cause great impact between the cup lip and the product.

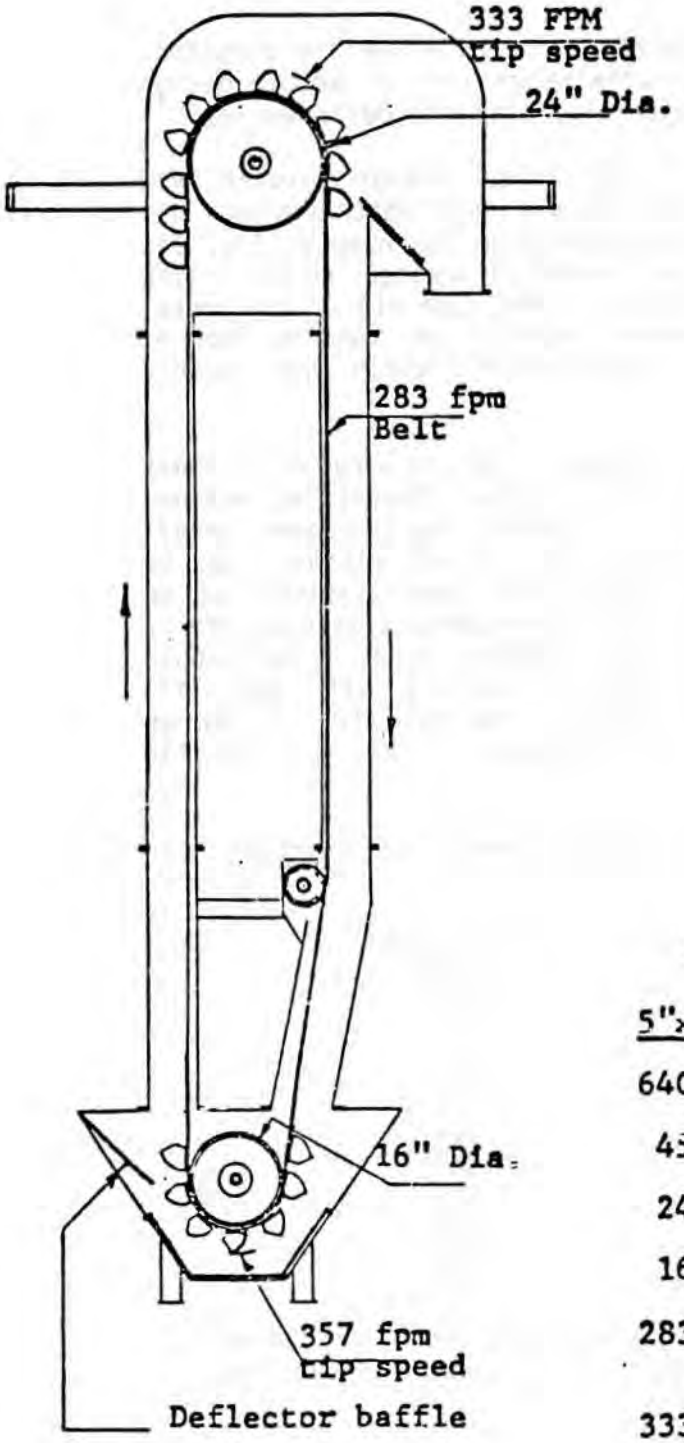
A comparison table below shows proper speeds for elevator head pulleys.

Head Pulley Dia	Head Shaft R.P.M.	Belt Speed F.P.M.
12"	60	158
16"	52	218
24"	45	283
30"	39	306
36"	37	349
42"	34	375
48"	32	402
60"	28.5	448

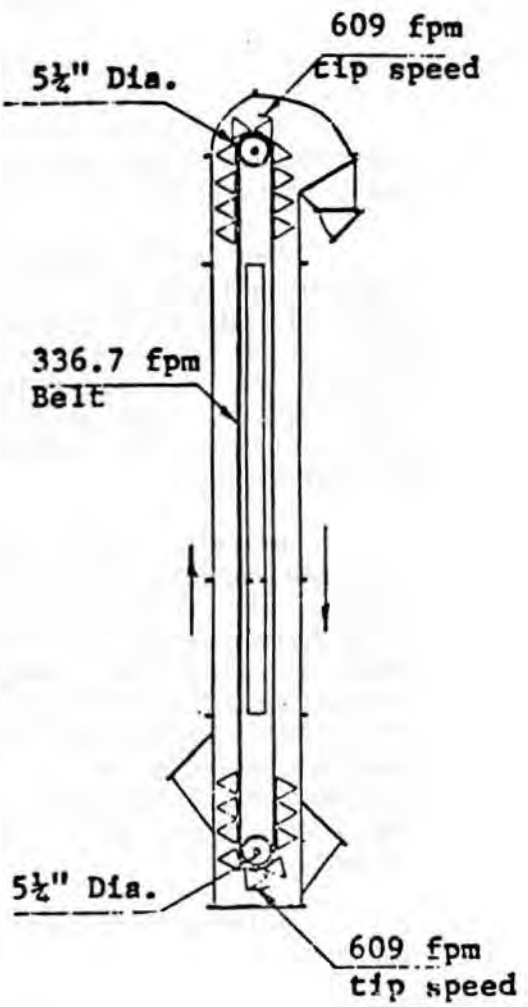
The larger the head pulley, the better the friction contact on the belt, avoiding head pulley slippage. If the head pulley slips, it allows leg plugging and the belting burns.

FIGURE #2

ELEVATOR "A"



ELEVATOR "B"



"A"		"B"
5"x4" Bucket		6"x4" Bucket
640 Bu.	Rated Capacity	700 Bu.
45 rpm	Head speed	245 rpm
24"	Head pulley Dia.	5½"
16"	Boot pulley Dia	5½"
283	Belt speed fpm	337
333	Cup tip speed over head pulley	609
6"	Bucket spacing	4½"

EFFECT OF PULLEY DIAMETER ON TIP SPEED OF BUCKETS

By using the correct speed elevator, buckets will discharge with proper trajectory so as to avoid product damage, excessive wear on metal surfaces, and will eliminate turbulence at the point of discharge. Turbulence will cause back-legging and poor flow of product into spouting.

One must recognize that the same centrifugal forces are in effect in the boot as in the head, although not as readily apparent.

Another key factor to consider in elevators is the manner in which a product is fed into the boot. Feeding on the up leg is considered standard because of feeding directly into the bucket, thus filling it to its best capacity. This might be true if all material fed alike and intake chutes were properly positioned. Generally speaking, however, non-fragile free flowing commodities are fed into the up leg. Easily damaged commodities such as very dry soybeans and edible beans should be fed on the down leg. Trashy or light products like bluegrass should always be fed on the down leg side.

Centrifugal elevators are not self-cleaning, but there are features that can aid in clean up. Pulleys can be equipped with solid ends and spacers can be inserted behind buckets. Boots can be equipped with full slide clean-outs, drop bottoms or with air suction adaptations.

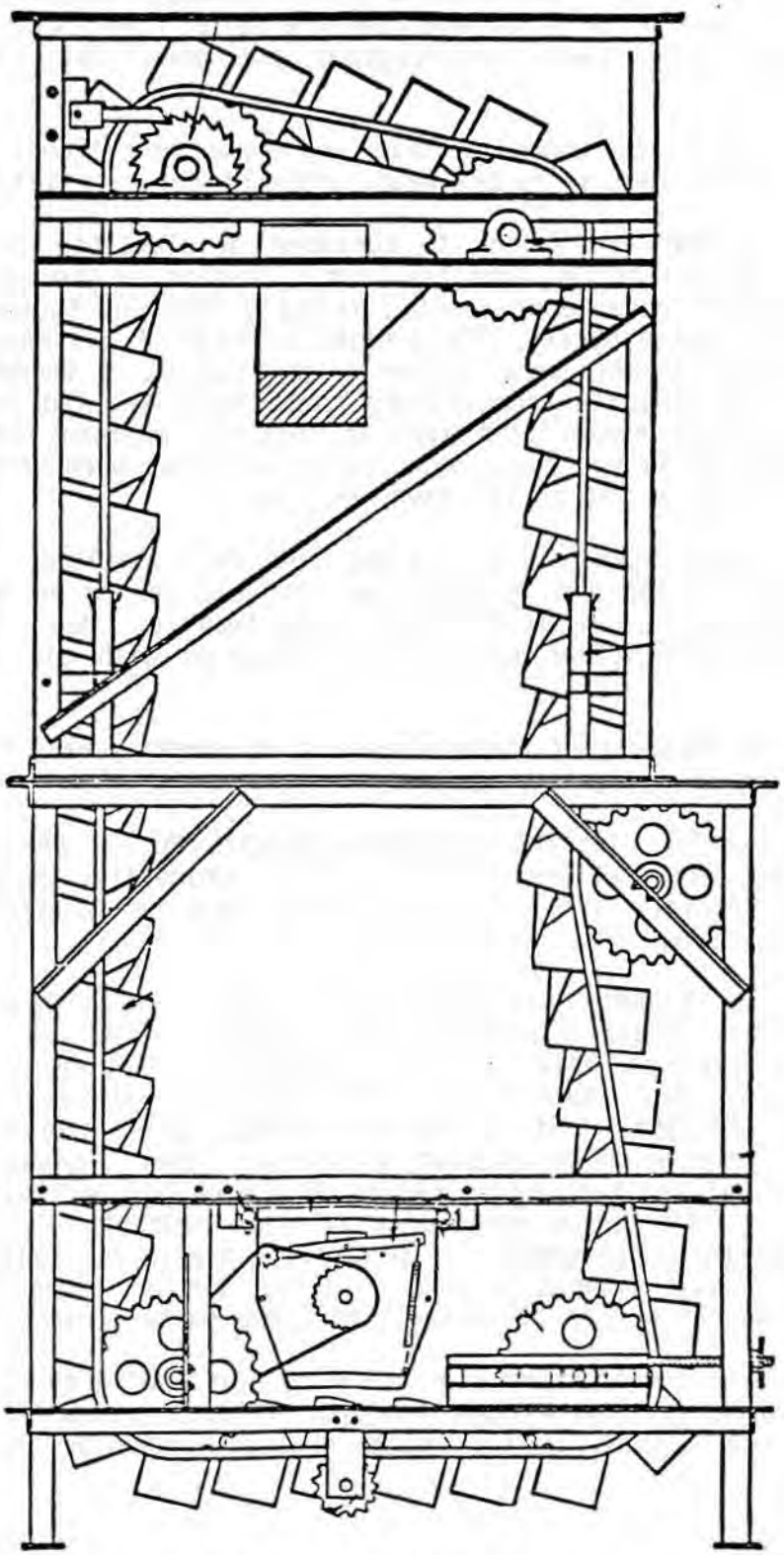
Maintenance of these elevators is normally very low unless basic principles of design are ignored.

Gravity discharge elevators (Figure No. 3) are manufactured in two types, external and internal design. Normally, we do not find the external gravity type in seed plants, but we do find the internal discharge type.

The buckets are mounted on chains in a "continuous bucket elevator". These elevators are ideally suited to handle fragile products such as edible beans. Loading is internal, by gravity or metering feeder. Buckets are close together with overlapping lips to prevent spillage. At discharge, buckets are inverted for internal dumping into a chute spouted to either side. Because buckets are attached between two chains riding on sprockets, various configurations at head or boot can be adapted to fit requirements. Buckets with up to four separate compartments can be used to handle four different products simultaneously without mixing. Using single compartments buckets, capacities range from 420 bushels to 2,000 bushels per hour.

Due to design and slowly moving overlapping buckets, the product is carefully handled without mixing. This is probably the most gentle way to handle seed. Units can be housed or unhoused depending on the

FIGURE #3



INTERNAL DISCHARGE ELEVATOR

installation. Damage or spillage of seed is held to an absolute minimum.

The chief opposition is greater use of internal gravity discharge elevators is the initial cost and greater space required. Nevertheless, if the operation demands gentle handling, minimum clean-up, no mixing and quick changeover of product or variety, then these units will answer your need.

Screw Conveyors

These units are one of the oldest means of conveying horizontally, on incline, and even vertically. They are available in a wide range of capacities and in either "U" trough or tube housings. They are not considered to be self-cleaning or to be gentle with friable products. They are adaptable for multiple inlets and outlets with the chance of a small carry over past intermediate discharges. Caution should be taken to prevent over-feeding.

Screw conveyors should not be used in a seed conditioning plant with the exception of the handling trash or screenings. They are difficult to clean and are considered abrasive on most seed.

Belt Conveyors

There are two kinds of belt conveyors:

A. Slider - where the belt runs over a pan that forms side walls and supports the belt. This is used for lengths up to 100 ft. for up to 6,000 bu./hr.

B. Idler - consists of a head and tail pulley and multiple rollers at angles to form the belt into a trough. This is primarily used in high volume operations carrying many thousands of bushels per hour.

However, smaller units are used for long runs to keep horsepower requirements down.

Belts are non-choking, well adapted to multiple feed points but poor multiple discharges. A tripper is the only really effective discharge device for a multiple outlet belt. Most trippers are too large and too dirty to use in seed operations. Spillage is bad.

Seeds are treated well on a belt, but cleanliness is a problem. Pan conveyors are not self-cleaning and are difficult to clean.

Generally, the heavier the material, the higher the belt speed: 700 RPM being the highest practical speed. Seed and light materials should travel about 200 RPM.

Maintenance is high.

Operating costs are low.

Inclines over 12 degrees are not good.

Initial cost is reasonable.

Vibrating Conveyors

The vibrating conveyor is 100% self-cleaning. Available in balanced and unbalanced models, its low cost and clean, damage-free operation is very attractive. The unbalanced unit can be used up to about 100 feet if firmly anchored; the balanced units, over 100 feet (but also anchored). Very few vibrating conveyors are available for use unanchored, since each one must be custom balanced and is, therefore, expensive.

While maintenance is low over the first couple of years, they can become unreliable when worn.

Stroke varies from 1/8" to 1", with speeds slowing as the stroke increases.

Vibrating units are non-choking, and the electric units with very short strokes are excellent modulated feeders.

Multiple inlets and outlets are possible, but carryover can be a problem.

Operation costs are low.

Initial cost is low.

Installation is simple on a firm base.

Cleanout is excellent.

Drag Flight Conveyors

A. Standard Drag - available in 6-inch to 36-inch units and capacities from 800 to 40,000 bu./hr: the single chain with nylon flights operates in a standard "U" trough. They are easy handling, and have fairly good cleanout. They can be readily inspected and repaired by local people. Using the by-pass inlet, they are non-choking and readily start and stop under load.

Power usage, especially in long runs is low, and multiple inlets and outlets are easy. Caution: there is a slight carryover on multiple outlets. While this can be reduced by addition of chain brushes, no guarantee is given on stopping entirely. Be sure to use lock-out valves at discharges to prevent mechanical mixture.

Price is about 1.5 times that of the screw conveyor but drive costs are less. Flights can be half-spaced for use on inclines.

B. "En Masse" Flow - used for large volumes in a small conveyor, the flighting is a plastic or metal bar at periodic intervals on a chain which runs near the bottom of the flat-bottom trough. The trough itself is filled nearly to the top with product, leaving only enough room for the return chain to pass. The material moves en masse as though it was on a belt and with very little abrasion. Costs are comparable to drag conveyors, but they are not widely used in clean seed operations because the chain running on the bottom causes seed damage. This conveyor operates more efficiently on material that is fibrous or trashy. As a rule of thumb - "if it's hard to get out of a bin, the en masse conveyor will work well."

Pneumatic Conveying

Pneumatic or air conveying has developed rapidly since the 1950s. It is employed to convey dry products from flour to products in all granular forms, including wood chips in lumber and pulp plants. Under development now is a unit to convey live chickens in broiler houses. One chief advantage is to convey assorted products for long distances through a combination of vertical, horizontal, and inclined pipes. They fit into compact areas and conveying runs are tightly sealed and self-cleaning. The few moving parts are located at the feed and discharge points only. Systems are used in complicated flour mills, corn and soybean oil plants, and plastic operations. They add appreciably to cleanliness and beauty of plants.

While these systems are highly successful, they are not as common in seed or grain operations due partly to the higher power requirements and because they are used only during seasonal operation. Each system must be engineered for established requirements. Also, seed plants handling fragile seeds may not be able to use pneumatic systems.

Very few seed plants use pneumatic systems to handle seed because of damage to fragile seed, high horsepower demand, and installation cost.

Gravity Spouting

Gravity flow is used for conveying wherever possible, yet spouting can be a source of product damage, wear, poor flow, or

choke-up. To select proper spouting, one must know something about the product flow, angle of repose, and the area of spout required for the volume.

On the chart below is shown the normal minimums I use in a plant layout:

Spout Angles Generally Applied

Product	Degree Slope	Carpenters Square
Wheat	30°	7/12.
Barley	33°	8/12
Oats	37°	9/12
Corn, dry (uncleaned)	37°	9/12
Corn, damp	45°	12/12
Soybeans	40°	10/12
Grasses (general)	45° (unless trashy)	12/12
Grasses, trashy	60°	20/12
Feed, ground	53°	16/12

The above chart is based on normal conditions, dry clean smooth piping and normal product. The slope should be increased above minimums if extreme contingencies demand.

The volume a spout is capable of handling is directly related to flow characteristics. Flow is determined by type and variety of commodity as well as moisture content. Square or rectangular spouting may be advisable if degree of fall is less than desired. Also, square spouting can be formed of heavy material with abrasion-resistant, or other type liner material inserted to prevent wear. The top side of square spouting can be bolted in place for easy access to liner replacement.

Joints of all spouting should be flush and as smooth as possible to avoid both product damage and turbulence which will rapidly dish-out metal surfaces.

Dead boxes are desirable on longer spout runs to decrease speed of flow and absorb impact of points of directional flow change. Many types are built but the self-cleaning types are preferred.

"E-Z Down" vertical ladders are used successfully to reduce cracking of soybeans, edible beans, and other fragile products. These

consist of rubber lined baffles, each in counter flow to the other, giving the material a walk down action. These are available in closed units for spouting or open units for inside bin let-downs. For best results, a starter box or trap is used to properly introduce the stream to the ladder.

In summary let's evaluate these basic characteristics of seed.

1. Flow - This governs the ability to bin, feed through cleaner feed mechanisms, flow across cleaning screens, and slope of gravity spouts.

2. Density - Applies more generally to weight in bins or against feed hoppers but also governs that light grass seed is not conveyed well on average speed belt conveyors.

3. Susceptibility to damage - Will usually clearly indicate what type of conveying equipment should or should not be used.

4. Moisture condition - This is of particular concern when handling such commodities as edible beans, soybeans and seed corn when moisture is low and susceptibility to cracking is high. Certainly, when designing a conveying system, the extreme or poorest conditions should be the governing decision in your selection.

5. Damage most feared - Equipment should be selected considering the product's susceptibility to damage.

6. Storability precautions - When thinking of seed stock, of course, no mixing can be allowed and breakage of certain commodities must be closely guarded. However, when handling market corn, for instance, some mixing can be tolerated, but breakage can be costly and a factor to proper aeration in storage. If final moisture of bulk commodities is on the higher side, breakage or improper cleaning causes a concentration of "fines" and is very risky.

Seed conveying is not high technical; it's common sense.

1. Know the products you will handle.

2. Plan your system to handle the products without damage or mixture.

3. Rely on competent equipment manufactures and their Rep's.

Remember the seed you are handling are "Living Organisms". The life you save may be your own!

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ECONOMIC ISSUES ARISING FROM CHANGE

Warren C. Couvillion[1]

There is an old Chinese curse that states "May you live in a time of change". We may look at this as absurd since all of us accept change very readily or at least we think we do. None of us really like to change. However, I feel that we are probably less bothered by change than our parents, and our children will accept change easier than we do.

In the past few years, the seed industry has seen several major changes. There will probably be more change in the industry in the next decade than there has been over the last few decades.

Factors producing change or evidencing change which have impact on the seed industry include:

FARMERS ARE MORE SOPHISTICATED

LESS POWER IN THE FARM SECTOR

INCREASED PUBLIC PRESSURE

CHANGING STRUCTURE IN THE SEED INDUSTRY

OPERATING IN A WORLD MARKET

BIOTECHNOLOGY

Current Situation in Mississippi

Before discussing the above listed changed, some information on current practices followed by Mississippi farmers will be discussed. During the 1983 crop year, a survey of Mississippi farmers was taken to ascertain their seed practices. Information was gathered on the cotton, soybeans, rice, and wheat crops. Farmers were asked about varieties planted, seed class, varietal selection, sources of seed, double cropping, and custom cleaning. Some of these results follow.

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[1]Ag. Economist, MSU; Computer Specialist, MCES/MSU; Management Systems Analyst, MAFES/MSU, respectively.

The estimated crop acreages of public, private, and unknown varieties are shown on Table 1. It can be seen that most of the soybeans and rice are planted to public varieties. In fact, there were no private varieties of rice reported. An interesting statistic of this table is that almost a half million acres of soybeans were planted to private varieties. This number would have been much lower a few years ago, if any existed at all. Private varieties have sold at a premium to the public varieties. Thus, firms are beginning to be repaid for some of their investment although it will take a much larger share of the market to be profitable. Profit will be delayed because these returns are just beginning to materialize and costs have been accumulating over several years. Wheat, a relatively new crop to Mississippi farmers, is almost all planted to private varieties.

Self pollinated crops indicate changes in farmers' habits for these crops over several years ago. Cotton seed has been handled in the private sector for several years. The 18 percent planted to public varieties is probably up from a decade ago.

It is interesting to note that Mississippi farmers plant extremely high classes of seed (Table 2). It is conjectured that these percentages probably run higher in Mississippi than in many other states, especially for soybeans and wheat.

Mississippi farmers used the Coop/Farm Supply stored at their major source of seed for all of the crops, as is shown in Table 3. Sources of soybean seed showed the most variation, as well as the highest percentage of seed saved. These results are what I would have expected. Our farmers in Mississippi use very little neighbor seed. Those of us associated with the seed industry hope that this does not change. If it indicates change, we view this change as positive.

The major influences for variety selections shown in Table 4 indicate that farmers rely heavily on past experiences in selecting varieties. They also indicate that variety trial information is important. This is viewed as an indication of the level of sophistication of farmers. The surprising number of this table was the extremely low influence that advertising had on farmers. Dealers' recommendations seem to have a much greater influence on varieties planted than advertising.

Farmers are More Sophisticated

Today's farmer has by necessity become much more sophisticated in his business dealings. Widely fluctuating prices, high interest rates, farm program alternatives, and the stagnating or the declining rate of increase in land values have forced farmers to become much more aware of the total business environment. The question now is more than "Will it grow?". "Will it pay?" is the question that needs to be asked

Table 3. Two main sources of seed planted, Mississippi, 1984

Source	Cotton	Soybeans	Wheat	Rice
	----------percent----------			
Saved	3.9	22.1	15.8	15.2
Coop/Farm Supply	78.7	57.1	77.5	84.8
Farmer/Seedsmen	7.8	11.8	6.7	0
Farmer/Not Seedsmen	2.2	5.5	0	0
Other	7.4	3.6	0	0

Source: Unpublished data from a 1983 survey of Mississippi farmers.

Table 4. Two main influences in variety selection, Mississippi, 1984

	Cotton	Soybeans	Wheat	Rice
	----------percent----------			
Planted Previously	45.2	56.0	50.8	58.3
Variety Trail Information	24.3	13.1	10.4	11.6
Dealer Recommendation	17.2	14.4	15.1	11.6
Advertising	2.6	3.0	2.1	0
Neighbor	5.5	6.6	3.8	0
Other	5.3	6.9	17.8	18.5

Source: Unpublished data from a 1983 survey of Mississippi farmers.

Table 1. Estimated crop acreage for soybeans, cotton, wheat, and rice for public, private, and unknown varieties, Mississippi, 1984

	Soybeans		Cotton		Wheat		Rice	
	000 Ac.	%	000 Ac.	%	000 Ac.	%	000 Ac.	%
Public	2,228.7	75.2	181.9	18.5	40.5	6.4	58.3	85.0
Private	450.2	15.2	763.2	75.2	477.8	75.8	0	0
Unknown	285.9	9.6	42.6	4.3	111.9	17.8	10.1	15.0
Total	2,964.8	100.0	987.7	100.0	630.3	100.0	68.4	100.0

Source: Unpublished data from 1983 survey of Mississippi Farmers.

Table 2. Class of seed planted, Mississippi, 1984

	Cotton	Soybeans	Wheat	Rice
	----------percent----------			
Registered	18.3	8.3	12.9	36.7
Certified	66.9	68.0	69.0	63.3
Originator[1]	11.8	1.5	0	0
Non Certified	3.0	20.7	13.8	0
Unknown	0	1.5	4.3	0

Source: Unpublished data from a 1983 survey of Mississippi farmers.

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[1]Private industry label--usually synonomous with registered seed.

and is being asked. This means that seedsmen have become and will continue to become more sophisticated. Such things as futures markets, call contracts, options, and computers have become a part of the everyday lives of farmers. Farmers who have not changed to meet the new challenges have often had to change occupations. Small farmers with everything paid for may be able to operate without a minimum of change, but those types of farmers are a vanishing breed.

In the past, the major risks farmers faced were production risks under rather stable market conditions. Now there are tremendous financial risks associated with these production risks. Some of the practices Mississippi farmers, and I am sure many others, have used to help avoid these risks are: increased irrigation, double cropping, and increased mechanization to insure timeliness of operation. What do these things mean to seedsmen? It means that new varieties will need to be developed to meet some of the newer management techniques used by farmers. Double cropping, no till planting, and irrigation may all require special varieties for maximum efficiency. If unexpected rains follow irrigation, a given farmer may have requirements for a drought resistant variety on one field and on the field next to it, need a variety that will be able to resist the effects of too much water.

The capital intensiveness of a farms' machinery complex may increase the pressure for varieties that will allow him to alter his production schedule to use his men and machines in the most economical manner. A systems approach to the farm will have to be tied back to the seed used, therefore increasing the pressure to become more aware of the total farm package rather than one variety of one crop.

Less Political Power in Agriculture

That there is and will be less political power in agriculture is not something new to you. This paper will not dwell on this matter except to state that these changes will force farmers and individuals operating in the inputs sector dealing with farmers to operate much more like other businesses. The traditional "Agriculture is a Way of Life" means that what many of us remember from our FFA days may be an obsolete approach to farmers.

The trend toward larger farms will probably continue. Along with this trend, we may see decreased roles in the agriculture support sector such as ASCS, extension service, farm oriented lending agencies, etc., as the numbers continue to decline. These changes will not be drastic, however, they will cause major changes over time.

Increased Public Pressure

This term is rather vague and can be taken several ways. What kinds of public pressure are now facing and will be facing seedsmen in the future?

Probably the most pressure will be the demand for quality. As pointed out elsewhere in this paper, timeliness of operations of highly mechanized farmers place a much greater burden to provide a quality product that will produce uniform stands. This is not new in the business, but what has surfaced in more recent years is the fact that settlements over seed problems are handled in courts of law rather than between the two individuals concerned.

This type of pressure will require firms to keep many more records than they have in the past. If a seedsman, because of poor seed quality has to incur the cost of replanting and a payment for decreased production due to timeliness, as well as the cost of seed; the bill for poor quality can be staggering. In some cases poor quality may not be the seedsman's fault. However, if he does not have documented proof of the quality of seed when it left his establishment or be able to show that seed from the same lot performed well elsewhere, he may have no recourse but to pay. Thus, the days of "running your own business on the back of a matchbook" as I was told by one of our seedsmen a few years ago are, or soon will be, gone.

Use of variety trial data gathered by an unbiased institution also puts pressure on your product to perform. These types of demands may be good or bad for your firm. Regardless of the outcome, increased pressure is placed on firms and there is little hope for anything but increased pressure.

Plant Variety Protection Act of 1970

This piece of legislation has had and will have the most significant impact on changing the structure of the seed industry since the widespread use of hybrids came into the industry. Even though the act has been in place for 14 years, its impact is only just now having an effect due to the nature of the time involved to develop new varieties and have them accepted by farmers. Farmers gave as their major reason for variety selection as "Planted Previously". This reason was given as one of the two main influences for planting 45 percent of the time for cotton and over 50 percent of the time for soybeans, wheat, and rice, thus the long time required for heavy private involvement.

Many of the large and some smaller corporations have developed protected varieties. These varieties are performing extremely well when compared to the public varieties. In fact, in Mississippi soybean trials the private varieties in most instances have outperformed public

varieties. A survey of 1982 farmer plantings showed that approximately 15 percent of soybeans planted were planted to private varieties. One of the major suppliers of soybeans said to me personally that his firm had sold over 40 percent of their bean seed under private label. Eleven different private labels were listed by farmers. If we think back only a couple of years, we can see that this is a significant increase. Looking ahead, the move to private varieties at a rapid pace seems eminent. I am not familiar with many of the other states, but here there are more than 10 companies developing soybean varieties adaptable to our state (also adaptable to Louisiana and Arkansas). The number of people doing similar work on public varieties is much, much lower. Given that breeders, as a group, are equal in abilities, the sheer numbers of people working in the private area would lead one to this conclusion. In many cases individuals working in private firms have access to a higher level of technology than is available to public programs. This has been magnified by tight budgets in both state and federal programs.

The potential returns to "building a better mousetrap" has been the prime mover to this increased interest. Many new entrants into the seed business are firms who are diversifying into other than their traditional areas. We have seen large drug companies, food companies, and other types of firms enter the industry. Some of the smaller companies who have historically built their business on expanding public varieties for planting by farmers have also entered the business varying degrees of success. They have entered either by purchasing rights to varieties or by developing their own through the hiring of breeders. One of the problems with free enterprise and private industry is that if left alone "it works". Thus, the finances to work for several years in a breeding program that may or may not be successful in producing the "better mousetrap" is beyond the financial scope of many of these firms. If you are small "you better be good" is a statement that bears truth in the seed industry.

Joint ventures between large and small firms already operating have made the transition from public to private varieties smoother than could have been the case for other types of industries. The large firm with a newly developed variety in many instances has acted in a very similar manner to that of the foundation seed program to provide basic seed for expansion. The difference being that the parent firm received royalties and the small firm has the rights to sell the variety in a local area. This arrangement has been beneficial to both parties in many cases. However, it should be noted that profits are usually the bottom line. When and if it becomes more economical to "do it yourself," the role of the small firm will diminish.

Seed conditioners may play an increased role in custom cleaning but custom cleaning is not the major source of income for plants except in isolated cases. The money to be made in the seed business is from purchasing seed at a small premium above grain prices and selling it at

seed prices. The margin in these types of operations are much greater than those received for custom cleaning (usually 200 percent or more above).

The above discussion leads to further thoughts of other segments of the seed industry that have traditionally played important roles. The segments I am speaking of lie very close to home. What will be the future roles of universities, foundation seed programs and seed certification programs. Some of their major traditional functions will be abandoned. It is probable that the magnitude of current roles will be altered. The sizes of seed certification agencies and foundation seed programs will probably be smaller. On the university side, changes will probably allow researchers to do more basic research since there will be some reduced pressure to release new varieties. In any event, it is felt that our farmers will be the primary beneficiaries from these changes.

Gravity Tables

In addition to a changing structure of the firms within the industry, there are some changes taking place within existing firms. In the conditioning side of the soybean industry, for example, there is an increased interest in the use of gravity tables in the conditioning line. If the reason for installing the gravity table is improved quality, firms are to be applauded. If the sole reason for installation of the gravity table is increased sales, your firm needs to take a hard look at the expense of adding these to your line. There has been some work in the physical value of the use of gravity, however, I do not have the answer from an economic standpoint. As stated earlier "Will it pay?" will be the determining factor for inclusion of gravity tables in soybean lines.

World Markets

One change that has to be made whether talking about inputs (seed) or inputs is that we face a world market for our products. This is more so true on the product side of the market. Often seed varieties are not well adapted to many areas and our markets may be limited in that respect. From 1970 to 1982, U.S. seed exports grew from $62 to $290 million dollars, an increase of over 450 percent (3).

Where are these markets for our seed? Our bordering neighbors accounted for approximately 32 percent while Japan and the EEC accounted for an additional 36 percent of our seed exports (3). Rossen pointed to the Mideast, South Korea, and Africa as major prospects for new seed business in the short run and Turkey, Yugoslavia, South Africa, and China as potential customers in the future. Vegetable and crop seed are

our major seed export crops. The two major crop seeds exported are corn and soybeans, respectively.

Firms should look at exports in the future for increased business. It is my feeling that we will see increased business. It is also my feeling that we will see increased exported in the future particularly if the trend of firms becoming larger continues. Many of the new owners and old owners in the seed business are already in the international market.

Biotechnology

One of the new "Buzz Words" is Biotechnology. If one thinks for a minute, all agriculture research that has been going on for years could have fit under this label. Dr. Delouche, in a series of articles in Seedsmen' Digest in 1983, discussed several technological issues that may drastically alter the seed business as we know it. The Plant Variety Protection Act of 1970 has altered the structure of the industry. We are seeing a shift in the size of firms and the location of some of the basic functions of the industry, however, the same basic functions are being performed, i.e., soybean breeding by private firms rather than universities. When discussing Biotechnology, we are talking about a change in the basic functions being performed that may be far more drastic than anything that we have witnessed thus far. Hybridization drastically changed the seed industry, however, seed are still produced in the field.

In the April 1983 article, Delouche states:

> The new Biotechnology being developed and positioned for exploitation is based one way or another on progressively deeper insights into genes, gene action and control, and the associated physiology of differentiation. The technology arising out of these insights provides the means to do things only dreamers dreamed about a few decades ago. [p. 10, April 2].

Some are particularly intriguing and many have far reaching economic effects on the industry. Some of these are cloning, gene transfers, somatic hybridization, somatic embryogenesis, and coatings.

Cloning

Cloning involves taking a bit of tissue from a plant and culturing it in a broth of nutrients and hormones (tissue culture). In some cases seedlings have been regenerated successfully in wheat and tobacco. Using this method of propogation, the sexual process which reshuffles traits is by-passed. The promising feature of cloning (making copies) is that the superior plant could be duplicated in enormous numbers (2).

Somatic Embryogenesis

Somatic embryogenesis is a process where tissue is taken from young embryos, floral stalks, or very young leaves. They can be cultured to form somatic embryos identical to the embryos in true seed, dispersed and induced to germinate and develop into a plant. Looking ahead, we can visualize the production of "cultured" seed in the laboratory (2).

Gene Transfers

Gene transfer is the transfer of genes or gene sets from one species to another (recombinant DNA technology). Monsanto announced last year that their scientists had successfully transferred a genetic trait from a bacterium to a plant cell. If one lets his mind wonder a bit, we can think of changes of awesome magnitude. One pointed out by Delouche was the conceivable potential to transfer the nitrogen fixation symbiotic mechanism from legumes to cereals, thus diminishing or eliminating the need for nitrogen fertilizer. Something like this could have tremendous effects on grain production world wide (2).

Somatic Hybridization

Somatic hybridization is a method of breaking down the barriers of sexual crossing from species to species. Protoplats from different species can be caused to fuse thus producing a hybrid cell from which a hybrid plant might (and has been) generated. Combined with tissue culture, cloning techniques could produce totally new plants combining the desirable traits of two sexually incompatable species. This process can also lead to mind boggling thoughts of what may lie in the future.

Coatings

Coatings have been used on the seed in the past but the surface has only been scratched. From the above discussion of the new biotechnology it follows that newly developed materials will require mediums to make them useful. Increased use of coatings may become a reality much sooner than some of the other techniques we discussed.

Delouche states:

> Increasingly, the seed is also being perceived and used as a convenient carrier of "applied" materials for the purpose of protecting the seed and developing plant against pests, influencing the growth and development of the plant, and/or modifying the environment in the vicinity of the seed in desirable ways. [p. 26, July 2].

Systemic fungicides, insecticides, micronutrients, and season long protection against certain diseases are now being applied to seed. Using crop seed as carriers of weed control chemicals is relatively new. There are many other innovations that are possible using modern coating technology.

Summary

The above mentioned "new technologies" will definitely play some role in the future. The question for many of these is, When?. The costs of putting these technologies has not received much attention, and rightly so, since many of these would fall in the category of basic research. Should some of the techniques become economically feasible we will see tremendous changes in the seed industry.

Many of the things presented in this paper point to an industry that will use much higher levels of technology in the future. Much of this technology will require large amounts of capital which point to larger and larger firms. The acquisition of smaller firms by larger firms has already begun. Those of us who remain complacent in our own little world will truly understand that the Chinese curse presented has true meaning.

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QUALITY ASSURANCE TECHNIQUES

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Emphasis: Vigor Tests

ACCELERATED AGING TEST

The accelerated aging (AA) test is useful in determining the storage potential of seed lots. High germination of a particular seed lot is not assurance that the lot will keep well in storage. Seed lots of equal germination do not have equal storage potential. Seed lots deteriorate rapidly under high temperatures and humidity. High temperature (approximately 42C) and a relative humidity close to 100% is used on a sample of any particular seed lot to obtain a pre-view of what the germination of that lot may be if it is put into storage for six months, one year or longer.

Material needed:

1. The main item needed is an accelerated aging chamber in which the temperature can be maintained at approximately 42C and a relative humidity close to 100%. Some arrangement must be provided to prevent condensate on the inside of the chamber from dripping on seed stored in the chamber. To maintain a high humidity it is necessary to keep a supply of water in the bottom of the chamber. The heating unit should either be installed below or in the reservoir of water so moisture "driven" off the surface of the water during heating will maintain the humidity of the chamber.

2. Containers which will hold 100 seeds of the kind(s) to be tested must be provided. These containers can be made of galvanized mesh wire or other material which will not inhibit air flow to the seeds.

Procedure:

1. Ordinarily four replicates of 100 seeds each of the seed lot(s) to be tested are counted and transferred to the AA chamber. Seventy two hours has been used for the conditioning period in the AA chamber with good success. However, any one intending to use the AA test should plan to conduct experiments to learn the length of time required to obtain meaningful results.

2. After the conditioning period the four 100 seed replicates are planted for germination in the usual way.

3. At the end of the regular test period germinated seedlings are counted. Generally a somewhat less critical application of germination standards are applied. Any seed is counted as germinable if it produces an identifiable root and shoot regardless of size or condition.

4. If desired, at the time the conditioned seeds are planted for germination 4 x 100 non-conditioned seeds from the same lot may be planted for a regular germination. It is sometimes helpful to compare the seedlings and the germination of conditioned and non-conditioned seed.

Conclusions:

The AA test can be used to predict the storage potential of seed lots. This test can be especially helpful to a seedsman who has several lots of the same variety and all of the seed of that variety cannot be sold before the planting season. The results of the AA tests on all his lots should provide the answer.

Acknowledgement:

The essential information for this write-up was taken from the paper by Delouche, J.C. and C.C. Baskin 1973. Accelerated aging techniques for predicting the relative storability of seed lots. Seed Science and Technology 1 (2): 427-451.

THE COLD TEST FOR CORN

The objective of the cold test is to evaluate the potential field emergence of corn seed under unfavorable field conditions (cold and wet).

Materials needed:

1. Plastic crisper boxes 7 1/2" x 10 1/2" x 4" with flanged lids have been used. However, any comparable sized (or somewhat larger) container with a tight fitting lid may be used.

2. A non-sterile sand-soil mixture consisting of two parts sand and one part soil are used. Care is used to obtain soil that has not been treated with an herbicide. The soil is screened through a 1/4" mesh screen to remove debri, then placed in a metal lined bin at room temperature and allowed to stabilize for two to three weeks before use. After the soil has stabilized, air dry mason sand is mixed with it in proportion of 2 parts sand and 1 part soil.

Procedure:

1. One measure (approximately one pint) of the media is placed in the container and evenly spread in the bottom. One hundred seeds are distributed on this layer, pressed down to keep the seeds in place and insure contact with the media. One measure of the media is placed over the seed covering it to a depth of approximately 3/8". Water is added in a calibrated amount to moisten the media to 70% of saturation. No additional water is added during the test.

2. Two replicates of 100 seed are planted. If less than 200 seeds are available for testing the total amount of seed is divided into two equal parts so it is a two replicate test.

3. The containers are then covered with their lids and placed on shelves in an insulated chamber cooled to 10C. After seven days the tests are removed from the chamber and placed on growing racks at room temperature (approximately 25C) with continuous light. The test is continued for an additional five days or until the seedlings raise the lids of the boxes. Seedling counts should be made soon after the lids are raised because the media will rapidly dry. Evaluation of seedlings into normal and abnormal is based on the "Rules for Seed Testing".

Conclusion:

Hybrid seed corn seedsmen in North America base their decision to sell or discard a seed lot on data from several sources and tests, including the cold test. Usually lots in which the cold test is below 80% may be retested several times to make certain of the seed quality. Seed lots that have a high regular germination but a relatively low cold test may emerge well and have good field performance under favorable conditions.

THE SEEDLING SHOOT WEIGHT TEST

The objective of the seedling shoot weight test is to determine, under laboratory conditions, the seedling vigor of a given seed lot. This test has been used to a large extent for corn and soybeans but can also be used for other kinds of crop seed.

Materials needed:

1. Three towels, 14" x 24" are used for each replicate of the test. The towel size and weight should remain consistent for all tests.

2. Plastic waste baskets, 7" x 11" x 12" are used as containers. Partions are made by puncturing holes in the sides of the basket and drawing light copper wire through the holes and across the basket. If the holes and wires are properly placed a maximum of 12 rolled towels may be placed in each container.

3. Poly-bags 16" to 24" long and with an opening sufficiently large to fit over the basket are used to keep moisture in the containers.

Procedure:

1. Two towels are dipped in water and allowed to drip dry. The towels should be wet but a water film should not appear if the towels are pressed with the thumb. The two towels are laid on a table and two rows of 25 seeds each are placed on the towels. The top row should be approximately 1 1/2 inches below the top, the second row 3 inches below the top. The seeds are oriented with the radical end towards the bottom of the towel and the germ side of the seed down. A third dampened (drip dry) towel is placed over the seeds and the three towels loosely rolled. An elastic band is loosely fitted over the roll below the seeds. At least four replicates should be planted for each lot. Each rolled towel is placed into the container with the seeds toward the top of the container. A poly-bag is pulled down over the container. At least 12" of the bag should protrude above the container so the seedlings will have plenty of room to develop. An elastic band is slipped around the container and bag to hold the bag to the container and prevent loss of moisture.

2. The containers are ordinarily placed in a dark room at 25 + 1C for seven days. Temperatures somewhat lower or higher than 25C may be used. However, a uniform temperature from test to test should be used.

3. At the end of seven days the towels are removed and a germination count made. The seeds are "cut free" from the normal seedlings. The

normal seedlings are placed in a coin envelope and dried in an 80C oven for 24 hours. The seedlings are then weighed to the nearest mg and the total dry weight of normal seedlings per towel divided by the number of seedlings included to obtain the average seedling growth rate in mgs.

Conclusion:

When conducting seedling shoot weight tests, more than one lot must be included in the test to provide a basis of comparison. At present, the test is valid only if lots of the same variety or genotype are compared. This test has been shown to correlate well with initial seedling vigor in the field -- which may or may not relate to final yield.

COOL GERMINATION TEST OF COTTON

Basis for the Cool Germination Test:

The Cool Germination Test technique is based on the premise that when cottonseed have been subjected to a sufficiently cool temperature for a determined period of time, this will result in a decreased germination and growth rate of weak and low vigor seedlings. This test differs from the cold test which is a pathological test in that it is a cool germination test conducted at a constant temperature of 18C.

Procedure:

The test is conducted on 200 seeds from each lot. Fifty seeds are randomly placed on each of 4 double layer 11" x 13 1/2" moist towels. Two additional towels are placed over the seeds before rolling. The rolled towels are then set upright in wire mesh baskets and placed in a dark, constant 18C germinator. The seeds are placed on the towels with a vacuum counting machine in the case of acid delinted seeds and by hand for machine delinted seeds. The towels should be moist, but not so wet that by pressing, a film of water forms around the finger. Additional moisture will probably not be needed. Only one count is made on the cottonseed and this count is made on the sixth day for acid delinted seeds and the seventh day for machine delinted seeds. All seedlings having a combined hypocotyl and root 1 1/2 inches or longer and normal for this length will be considered as high vigor seedlings at the end of the test period. The measurement is made from the tip of radicle to just below seed or leaf structure. The remaining seeds or seedlings are not counted in the vigor test percentage. All seeds used in this test must have been treated with a recommended fungicide.

TETRAZOLIUM TEST

The tetrazolium test is widely recognized as an accurate means of estimating seed viability. The test is used throughout the world as a highly regarded method of estimating seed viability and is a routine test in many seed testing laboratories. It is often referred to as a "quick test," since it can be completed in only a few hours, as compared to regular germination tests that require as long as two months for some species. Tetrazolium test results can be extremely valuable for providing labeling information for immediate shipment of seed lots without waiting for completion of germination tests. It is also a valuable research technique for estimating seed viability and determining reasons for poor germination.

Principle:

The tetrazolium test distinguishes between viable and dead tissues of the embryo on the basis of their relative respiration rate in the hydrated state. Although many enzymes are active during respiration, the test utilizes the activity of dehydrogenase enzymes as an index to the respiration rate and seed viability. The highly reduced state of the dehydrogenases enables them to give off hydrogen ions to oxidized colorless tetrazolium salt solution, which is changed into red formazan as it is reduced by hydrogen ions. Seed viability is interpreted according to the topographical staining pattern of the embryo and the intensity of the coloration.

Procedure:

Seeds are first soaked in water to allow complete hydration of all tissues. For many species, the tetrazolium solution can be added to the intact seed. Other seeds must be prepared by cutting or puncturing in various ways to permit access of the tetrazolium solution to all parts of the seed . After hydration, the seeds are placed in a tetrazolium salt solution and held in a warming oven at about 35C for complete coloration. Two hours is usually adequate for seeds that are bisected through the embryo, but others require longer periods of staining. If seeds are held too long in contact with the tetrazolium solution, they tend to become overstained, making interpretation difficult. A handbook of information and instructions for performing the tetrazolium test has been published by the Association of Official Seed Analysts.

Evaluation:

Although the tissues of living seeds stain red, their interpretation as an estimate of viability requires considerable skill and experience. Sound embryo tissues absorb tetrazolium slowly and tend to develop a lighter color than embryos that are bruised, aged, frozen, or disturbed in other ways. The experienced analyst learns to distinguish between seeds with the capacity to produce normal seedlings and those that stain abnormally.

The tetrazolium test is often called the topographical tetrazolium test because of the pattern or topography, of staining is an important aspect of its interpretation. Many seeds are neither completely dead nor completely alive. The staining pattern reveals the live and dead areas of the embryo and enables the analyst to determine if seeds have the capacity to produce normal seedlings. The cell division areas of the embryo are most critical during germination, and if they are unstained, or abnormally stained, a seed's germination potential is weakened. The analyst must be familiar with crucial cell division areas of the embryo and learn to interpret their staining pattern in terms of seed germinability.

Other factors must be carefully observed when interpreting a tetrazolium test. Among these are flaccid tissues (lack of adequate turgor) and critically located fractures, bruises, and insect cavities. Any of these factors, when present in a vital position, may cause an otherwise sound seed to be nongerminable.

Source of Tetrazolium

Tetrazolium may be obtained from most chemical supply houses. One source is listed here for your information.

Fisher Scientific Company
Chemical Manufacturing Division
Fair Lawn, NJ 07410

MEASUREMENT OF LEACHATES
(Conductivity Test)

As seeds age and natural deterioration proceeds, degradation and disorganization of cellular membranes may occur, allowing nutrients to be leached from them in the presence of water. Loss of seed vigor can be detected by an increase in seed leachates in the presence of water.

Leaching in older, deteriorated seeds may be due more to available sugars (glucose, fructose, sucrose, raffinose, maltose, and xylose) than to changes in membrane structure and permeability. Better seeds with higher vigor are better able to consume soluble sugars than lower vigor seeds. This leads to a lower concentration of soluble sugars in better seeds and ultimately to a lower rate of leakage into the water medium. In contrast, the less vigorous seeds are unable to utilize these soluble sugars rapidly and lose them to the imbibing solution through diffusion, osmosis, and active transport. Leachate tests for monocotyledonous seeds, where most reserve food storage is in the endosperm, must be interpreted with great caution, since some loss of nutrients could occur without perceptible effect on vigor. In cases where slight mechanical damage occurs to the endosperm, injured seeds may leak at least twice as much sugar as uninjured seeds; yet differences in their germination may be minor. Tests with artificially aged seeds have shown that germination of aged seeds may be completely lost without any increase in their leakage of nutrients. Thus, sugar measurements are not always a reliable index of seed viability. Furthermore, the leaching of sugars may be regulated primarily by sugar utilization rather than changes in membrane permeability.

The concentration of leachates may be measured by electrical conductivity methods or by chemical methods. The conductivity test was originally developed to aid in the detection of wrinkled pea and seed lots which, although of high laboratory germination, were liable to pre-emergence failure in the field. Some lots of seed which are losing vigor release materials, such as sugars or other electrolytes, in solution into the soil which may increase the activity of soil fungi. This increase in the activity of soil fungi may interfere with the development of the seedling, especially under cold or wet conditions when germination is slow. This susceptibility to pre-emergence failure can be detected by soaking seed in deionized water and measuring the amount of electrolyte leached out by determining the electrical conductivity of the water. Samples which release large amounts of electrolytes give a high reading and may not be suitable for early planting; if very high values are obtained the seeds may not be suitable for planting at any time.

As is the case for many vigor tests, the leachate tests is not the ultimate answer in the search for the ideal vigor test and has not been accepted widely as a routine testing method. It is useful, however, if properly performed and interpreted, and has helped increase our understanding of seed vigor.

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