Closer Look at Seeds.

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A CLOSER LOOK AT SEEDS

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Each person who uses seed for earning his living soon learns to distinguish among seed of different species on the basis of their characteristic size, shape, color or similar visible differences. Although not as apparent or diverse, the same seed have characteristic differences in their chemical components and the structural relationship of the principal seed parts, i.e., embryo, cotyledons, seed coat, etc. The purpose of this paper is to review some of the major differences in the chemical composition and structural arrangement of seed and to examine the effects of these two factors on seed viability and longevity.

Though frequently suggested, it is not likely that plant breeders can develop seeds of any species that are less subject to mechanical injury, will dry more easily or will be of inherently greater longevity. Taking a closer look at the chemical and structural make-up of seed should assist each of us to determine those practical conditions most desirable for seed, because trying to find a seed which can withstand the physical and environmental conditions to which we frequently subject them is an essentially fruitless effort.

There are several basic botanical facts which are true for all seed that should be remembered. Five of the more important of these facts are as follows:

(a) A seed must be alive to be of value for reproduction.

(b) Seed of different species vary in their natural life spans.

(c) Within each botanical species, there is some variation in the chemical and structural make-up of the seed of different varieties and, further, seed of the same variety can vary in percentage oil, protein, and carbohydrate.

(d) Moisture content has the most dramatic effect on a seed's longevity and susceptibility to injury when other conditions are equal.

(e) All seed are hygroscopic (except hard seed).

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Chemical Differences

There are three general catagories into which natural chemical substances are classified: (a) fats or oils, (b) proteins and (c) starches or carbohydrates. All seed of major importance contain at least a trace of each of these substances. Therefore, what is meant by the expression "high oil" seed, for example soybeans, is that it has a higher percentage of oil than other seed kinds. In reality many "high oil" seeds have a greater percentage of protein or carbohydrate than oil or fat. Table 1 shows some of the more important seed kinds when classed on the basis of their chemical composition.

Table 1. Classification of Some Important Crop Species According to the Chemical Composition of Their Seed.

"High Oil" 18-50%	"High Protein" 18-50%	"High Starch" 50%
Soybean	Austrian Winter Peas	Corn
Cotton	Alfalfa	Carrot
Castorbean	Beans, Snap	Fescue
Flax	Cowpeas	Grain Sorghum
Peanut	Crimson Clover	Oats
Sunflower	Hairy Vetch	Rice
	Lespedeza	Sudan Grass
		Wheat

What factors are most affected by the chemical composition of the seeds? The major factors are moisture content, rate of deterioration and susceptibility to mechanical injury. To simplify the task of classifying seeds on a chemical basis, seed kinds typical for the three major chemical substances will be used. These typical seed and their catagories are: soybeans (high oil); Austrian Winter peas (high protein) and corn (high starch). Table 2 shows the average chemical analysis of the seed of these species.

Table 2. Chemical Composition of Three Seed Kinds.

Seed Kind	Crude Fat %	Protein %	Total Carbohydrates %	Initial Moisture % (5°C-50% R. H.)
Soybean	19.7	37.9	35.3	8.6
Austrian Winter Peas	1.0	22.3	66.5	10.9
Corn	4.3	8.0	77.3	11.5

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The influence of chemical composition on the moisture content of seeds will be considered first. Remember, all seed are hygroscopic. They absorb moisture from the environment until an equilibrium is reached between the moisture content of the seed and the relative humidity of the surrounding atmosphere. The quantity of moisture in a seed at equilibrium is directly related to its chemical composition.

In general, the equilibrium moisture content of a "high starch" seed, such as corn, is higher than that of a "high oil" seed, such as soybean, under the same atmospheric conditions. This phenomenon is true because oils don't mix with water. An example should clarify this point. Think of a corn and soybean seed of equal weight, say 10 grams. By referring to the data presented in Table 2, it is apparent that about 8 grams or 80% of the soybean seed will absorb water (10.0 grams total weight less 1.97 grams crude fat), while 9.6 grams or 96% of the corn seed will absorb water. Thus, if moisture is removed from both seeds and then measured, the corn will contain more water because of the greater amount of moisture absorbing starch and protein.

Note that the preceeding paragraph started with the words, in general. A more critical examination of the relationship between a seed's chemical composition and its moisture content, reveals exceptions to this general rule.

To show these exceptions, let's review the results of an experiment which placed the three chemically different seed kinds. shown in Table 2, into storage conditions of 20°C and relative humidities of 35%, 75%, and 93%. The initial moisture equilibriums were: 11.5% for the "high starch" corn; 10.9% for the "high protein" Austrian winter peas, and 8.6% for the "high oil" soybeans. Notice that these moisture contents are in keeping with the general statement.

When the seed were placed in the 35% R.H. chamber, they lost moisture at about the same rate, and the general rule is still true since the "high starch" corn has the highest moisture content and the "high oil" soybeans the lowest (Figure 1). Figure 2 shows that at 75% R.H., the "high oil" soybeans still have the lowest moisture content. However, the differences among the seed kinds is diminished with the "high protein" Austrian winter peas having increased 3.6% in moisture, the "high oil" soybeans 3.8% and the "high starch" corn only 2.4%.

At 93% R.H. this general rule completely breaks down, as shown in Figure 3. The moisture equilibrium of Austrian winter peas and soybeans are essentially the same, 20%, while corn has reached a moisture content of only 18%. Why this shift in moisture absorption at high relative humidities? It was apparently due to the protein which is relatively high in both the peas and soybeans.

A summary of this work indicates the following effects of seed chemistry on moisture content: (a) at relative humidities below 75%, equilibrium seed moisture is inversely related to oil content, (b) the protein content of a seed has

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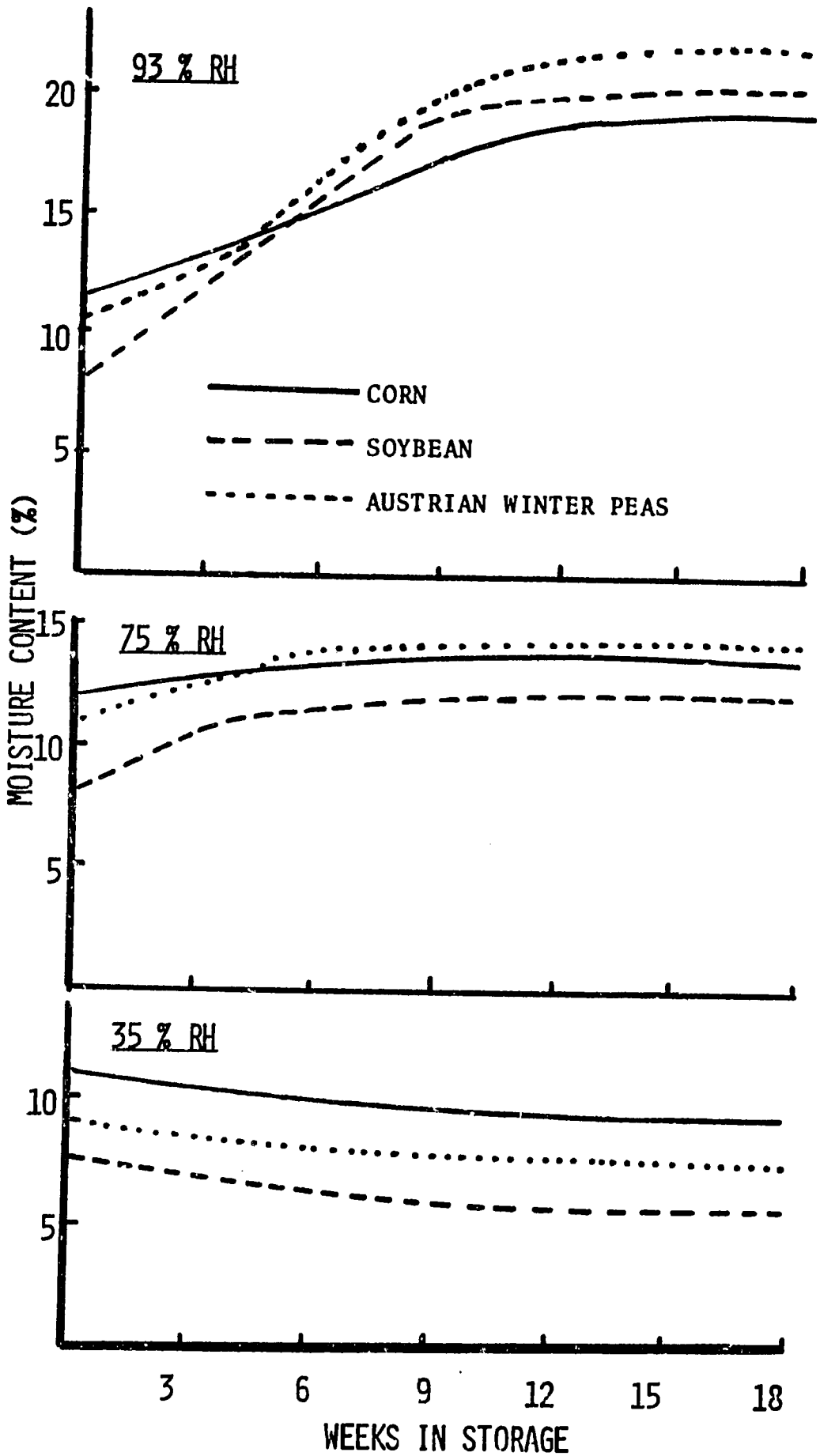

Figure 1. Moisture contents of three seed kinds at different levels of relative humidity.

little influence on its equilibrium moisture at relative humidities less than 75% and (c) the influence of starch on equilibrium moisture content is about the same at all relative humidities.

The establishment of moisture equilibrium in seed is a time dependent process. This means that the day to day fluctuations in temperature and relative humidity have little effect on the moisture content of seed stored in the warehouse. However, seed produced in a "low humidity" area that are subsequently shipped to a "high humidity" area will increase in moisture content over a period of four or five weeks until the equilibrium is restored.

Speed of deterioration is another factor greatly influenced by the chemical composition of the seed. Normally, as the percent oil in the seed increases the speed of deterioration increases. In most "high oil" seeds the oils or fats start to deteriorate soon after the seed reaches physiological maturity. This deterioration process will continue until the seeds are properly dried and then stored under conditions that can slow this process. Our research indicates that once deterioration starts, it can not be completely stopped.

When considering the effects of oil content on seed life, it is not wise to generalize too broadly. For example, cotton and soybean seed are both high in oil, high in protein and low in starch. In spite of these similarities, undamaged cottonseed will store well under ambient conditions in the U.S. for about 24 months while soybeans of equal, initial quality will maintain satisfactory germination for only 12 months.

Another way in which the chemical components affect seed is in the susceptibility to mechanical injury. Starches, as they occur in seeds, are classified as either soft or horny, i.e. hard. The soft starch is generally white in color while the hard starches tend to be translucent. In dent corn we find both types in the same seed and it is the greater shrinkage of the soft starch when the seed passes physiological maturity that causes the characteristic dent.

Mechanical injury comparisons between two "high starch" seeds such as dent and flour corn (Indian corn), will show the floury corn to have more mechanical injury because of its greater quantity of soft starch. In rice, another "high starch" seed, we often find that the natural stresses created during the drying of the starch, as the seeds mature, are sufficient to create a fracture across the endosperm. This is called "sun-checking". If we remove the hull of such seeds, they will be classified as broken seed and they appear to be mechanically injured. Many of the "high protein" seeds, particularly lima and snap beans, become extremely fragile at moisture contents required for safe storage. This fragility increases as moisture content decreases and is directly related to the chemical composition and cell structure of these seed.

To summarize the effects of chemical composition on seed, keep these

points in mind:

1. Seed longevity is a characteristic of a species and is influenced by the chemical composition.

2. There is some natural variation in the chemical composition of seed within each species.

3. Seeds are hygroscopic.

4. Seed moisture has a dramatic effect on a seed's longevity and susceptibility to injury than temperature under normal storage conditions.

5. At temperatures below 40°C and average relative humidities below 75%, "high oil" seed will have lower moisture contents than "high starch" seed at the same relative humidity.

6. Under most climatic conditions "high starch" and "high protein" seeds will maintain their viability longer than "high oil" seeds.

7. Some "high starch" and "high protein" seed are very susceptible to fracturing damage due to the physical properties of different starches and proteins.

Structural Differences in Seeds

Let us now consider some of the basic structural differences in seed which are often overlooked or ignored. Do not confuse structural differences with physical differences, i.e., size, length, width, thickness, color, roundness, specific gravity and seed coat texture, although, the two are related.

Natural differences in structure among seed of different species also affect susceptibility to injury, moisture absorption and longevity. For the purpose of this discussion, seed have been classified into 5 categories based on their structure. These categories are: (a) "weight protected seeds", (b) "structure protected seeds", (c) "loose filled seeds", (d) "naked fruits" and (e) "naked seeds". Table 3 shows the classification of 20 of the most important species according to these categories.

Table 3. Classification of Selected Crop Species According to Structural Differences in Their Seed.

1. Weight Protected Seeds

Fescue
Carrot

2. Structure Protected Seeds

Alfalfa
Flax
Hairy Vetch
Lespedeza, Common
Sudan Grass
Rice
Oats

3. Loose Filled Seeds

Cotton
Castor Bean
Peanut, Unshelled
Sunflower

4. Naked Fruit

Corn
Grain Sorghum
Wheat

5. Naked Seeds

Soybean
Peanuts, Shelled
Austrian Winter Peas
Beans, Snap
Cowpeas
Crimson Clover

Weight protected seeds

A seed typical of weight protected seed is tall fescue. Seed of this category are usually protected by the natural accessory parts that remain attached to the seed. This protection arises from the fact that the seed, as it is normally encountered, is so light that it escapes damage. When dropped, the seeds do not gain sufficient velocity to be injured or when hit, the seed offers very little resistance to the object which strikes it. There is a tendency for some of the seed in this group to change several percentage points in moisture with no appreciable change in physical dimension, thus an increase in weight per bushel may be observed with minor increases in moisture content.

Most seed of this category are quite susceptible to cutting and crushing because the seed coverings, usually the lemma and palea, are not mechanically strong. An example of this principle is demonstrated by dropping a feather and an egg simultaneously. The lighter feather isn't affected like the egg.

Structure protected seed

As the name implies the seed in this classification are protected by either

their accessory structures or seed coats. Alfalfa is representative of this group. Even though the radicle is rather exposed due to the seed's structure, the seed coat is relatively thick and hard and offers excellent protection to the embryo. However, not all small seeded legumes fall into this category.

Sudangrass is also representative of this group. Although, structurally the "hulled" seed is essentially the same as grain sorghum, a "naked fruit", the tough, durable lemma and palea gives excellent protection against mechanical injury. Seeds having this type protection can be equated to an inflated balloon placed in a heavy paper bag and then dropped on a pin. The balloon does not break as long as its "protection" is in place, but remove the bag and the balloon, representing a hulled seed, is destroyed by the same treatment.

Loose filled seeds

Seed of this category are those which are characterized by a comparatively thick, tough, rigid seed coat or covering such as that found in cotton and unshelled peanuts. The covering acts as an excellent protectant for the fragile embryo under normal conditions. It has been proven that seed quality problems occur when this protective cover is broken, nevertheless, the protective covering is crushed, cut and sometimes removed by mechanical equipment and each year we sit and wonder why these "tough" seeds can't take it.

Another characteristic of this grouping of seed is that as the seed mature, the seed coat will develop to a predetermined size, but the embryo may not completely fill the space provided. This leaves an air space inside the seed coat. As a result, when we measure the seeds dimensionally, they are the same size but often differ in specific gravity because of different amounts of air space. This characteristic will permit separation on the basis of specific gravity.

There is a rule of thumb that states "as seed moisture increases, test weight per bushel decreases." This rule is based on the fact that seed increase in size as moisture content increases and this absorption of water, because water is lower in specific weight than seed materials, causes a decrease in weight per bushel. This rule does not hold true for this category of seed because the seed coat remains constant in size as the internal parts of the seed expand and contract with changes in moisture.

This principle is easily demonstrated. Measure the circumference and weight of an empty shoe box, then open the box, place a brick inside, and repeat the measurements. Naturally the circumference of the box remains constant, but the weight, therefore, specific gravity increases. However, if we start with a full box, any material added will result in a change of circumference and weight. If the added material, such as water, is lower in specific gravity than the seed materials, there will be a decrease in specific gravity.

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Naked fruits

Botanically, the "seed" of the grass family are really fruits which have a seed imbedded in them, thus, the classification "naked fruits".

In this category, of which corn is typical, some protection is afforded the embryo by the endosperm which encircles it on three sides. Thus, simply by chance three out of four injuries will occur to the less vital endosperm and, although weakened the seed will produce a plant, if the damage has not affected the embryo. However, this protection is somewhat deceiving and under the right circumstances just a slight shock will destroy this protection in the region covering the embryo.

An additional problem arising from the positioning of the embryo in seed of this category arises after seed maturity, but while the seed are still on the plant. The embryo of seed of this category are positioned in the plants' accessory structures in such a way that they are frequently surrounded by moisture following a rain. For this reason, sprouting or serious deterioration of the seed occurs before they are harvested. Fortunately, some of these seed have a natural dormancy or the "sprouting" problem would be much worse.

Naked seeds

The last category of seed are classified as "naked" seed. As the name implies, they have very little natural protection and almost any handling will expose and damage the embryonic axis and the two cotyledons. A seed typical of this category is the soybean.

Most naked seed belong to the legume family and are formed inside a pod. When these seed are harvested, we remove this protective pod and expose the seed to all kinds of deteriorative effects. Moisture readily passes through the thin seed coat, except when it contains waxy substances, which gives very little structural protection to the embryo. Additionally, the structural weaknesses, thin seed coat, exposed embryo, etc., are often found in association with similar undesirable relationships attributable to the chemical constituents in the seed, as previously discussed.

Probably the most delicate seed is the shelled peanut. This seed combines all of the undesirable structural and chemical characteristics. Nevertheless, every year thousands of tons of high quality peanut seeds are harvested, dried, stored, shelled and marketed. How is this possible? It is because, with peanut seed producers, the seed comes first and the methods of handling and storing peanuts have been adapted to the seed's characteristics. Thus, we can learn from those who have experience in handling a truly delicate seed. The first and most important lesson is FIRST THE SEED!

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In summary, by utilizing our general knowledge about seed and combining these facts with the known effects of a seed's natural chemical and structural properties, it is possible to increase our understanding about seed. To do this, recall the chemical and structural categories into which the seed were placed during this discussion as given in Tables 1 and 3. The relative effect of chemical composition on seed quality can be obtained by assigning a numerical rating 6 to "high oil", 3 to "high protein" and 2 to "high starch" seeds. To similarly reflect differences in structure the following scale can be used: 1 for "weight protected" seeds; 2 for "structure protected" seed; 3 for "loose filled" seeds; 4 for "naked fruits", and 5 for "naked" seed. In both ratings, the higher the rating, the more susceptible the seed are to damage.

Refer to any species in the left hand column of Table 4, and multiply its structural classification rating by the chemical classification rating and the result will be an index value which is called the damage susceptibility index or DSI. The DSI is a relative rating of a seed's susceptibility to mechanical injury and the deteriorative effects of high moisture and temperature. The DSI can be used to quickly give an indication of relative difficulties one can expect to encounter when handling different seed kinds. Additionally some DSI values rather strongly suggest the need to exercise far greater precautions, than are presently used, in handling seed of some species, cotton for example.

Remember that the DSI values are relative values, therefore, species not differing by more than 3 in DSI value normally can be handled in a similar manner without danger of violating the natural characteristics of the seed. The DSI will not lessen the need for each of us to learn all we can about the specific charateristics of the seed that we handle.

In conclusion, by using the damage susceptibility index as a guide for harvesting, drying, processing and storing of seed, many of the seed quality problems encountered each year will not occur and the severity of others will be reduced. As seedsmen, we have ignored nature's seed laws long enough, therefore, lets stop, now, and take a closer look at seeds.

Table 4. Damage Susceptibility Index (DSI) for Seed

Structural Classification	Chemical Composition		
	High Oil (X6)	High Protein (X3)	High Starch (X2)
A. Weight Protected (X 1)			
Carrot			2 1/ 2/
Fescue			2
B. Structure Protected (X 2)			
Alfalfa		6	
Flax	12		
Hairy Vetch		6	
Lespedeza, Common		6	
Oats			4 2/
Rice			4
Sudangrass			4
C. Loose Filled (X 3)			
Cotton	18		
Castorbean	18		
Peanuts, Unshelled	18		
Sunflower	18		
D. Naked Fruit (X 4)			
Corn			8
Grain Sorghum			8
Wheat			8
E. Naked Seeds (X 5)			
Soybean	30		
Peanut, Shelled	30		
A. W. Peas		15	
Beans, Snap		15	
Cowpeas		15	
Crimson Clover		15	

1/ Increasing DSI values indicate the need for greater precautions in handling and storage to maintain seed quality.

2/ Seed of species not differing by more than 3 in DSI value normally can be handled in a similar manner.