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Soybean Seed Storage Beyond One Year

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SOYBEAN SEED STORAGE BEYOND ONE YEAR

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Background

The rapid expansion of soybean acreage and production in the USA beginning in the early 1950s has been paralleled by an increasing demand for quality seed. Soybean producers recognized early in their experiences with "grain type" varieties that soybean seed were somewhat different from the seed of most of the other crops with which they were familiar, e.g., corn, wheat, oats, rice, cotton, sorghum. Germination of soybean seed even just after harvest was often too low for planting. In years when germination was satisfactory after harvest, it frequently dropped to an unacceptable level by the next sowing season.

The traditional "seed saving" practices used by farmers for other kinds of non-hybrid seed did not work too well with soybeans. Through experience and the installation of basic facilities such as aeration bins, some farmers did learn to produce and store soybean seed of satisfactory quality for planting in most years. Others, perhaps a majority in some regions, turned increasingly to the specialized, professional soybean seed producer or company for all or a major portion of their seed needs.

Production and marketing of soybean seed is not without problems and risks even for the specialists and professionals. Their expertise, facilities and other resources, however, and their concentration on the task of maintaining seed quality have led to the development of a widespread, responsible soybean seed industry capable of delivering good to high quality seed in quantities that are usually sufficient to meet the needs of farmers.

The soybean seed industry is confronted with the near chronic problem—among many—of inbalances between supply and demand, especially on a variety basis. Supply overages or shortages resulting from higher or lower-than-expected yields, better or lower-than-expected quality, and so on, and which are recognized after harvest but before processing can usually be satisfactorily resolved. Seed production contracts often contain a clause stipulating the maximum quantity of seed that will be accepted.

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Thus, the over-supply is left with the contract producer. In the case of shortages, the seedsman can usually locate another seedsman with an over-supply of the desired variety and improve his supply position.

The most damaging inbalance between supply and demand is an over-supply of seed of specific varieties that does not become apparent until after processing, packaging and storage, and often not until just before the sowing season. The planting intentions of farmers do not begin to firm up until the new year and are subject to frequent change thereafter. Favorable prices for alternative crops such as corn, cotton and rice as compared to soybeans cause shifts in acreage away from soybeans. Lower prices for soybeans force out the low-yield producer operating on marginal land. Good weather in late April and May prompts last minute decisions to "go-with" more cotton or corn, or with a larger acreage of "early maturing" varieties than planned. Conversely, poor weather conditions during this period lead to a shift in varietal preference to the "later maturing" varieties.

For the seedsman the consequences of these situations singly and in combination are stacks of unsold, processed, packaged, inspected and labelled seed in the warehouse. Since it has been well established that "carrying over" soybean seed in unconditioned storage is at best a risky practice, the main alternative available to the seedsman is to "burst" the bags and send the seed to the grain elevator at a substantial loss.

Methods and procedures for "carrying-over" soybean seed with minimal risk and satisfactory maintenance of quality would greatly reduce the losses sustained by seedsmen from late-in-the-season changes in farmers planting intentions. They would also permit maintenance of 10 to 20% reserve stocks of selected varieties of foundation and registered class certified seed or the equivalent as is the practice for other kinds of seed.

Storage for One Season

The first hurdle in storing soybean seed "beyond one year" is to get them through the first season or year in good condition. The "one season" or usual storage period for soybean seed is about 7–9 months. It begins with harvest and ends at planting time the following season. The period usually consists of a bulk seed storage phase and a packaged seed storage phase.

The storability of soybean seed is largely controlled by the interaction of four factors: (a) inherent characteristics; (b) quality of the seed at the time it enters storage; (c) temperature; and (d) seed moisture content and ambient relative humidity. Since these factors are operative regardless of the storage phase or period, anyone concerned with storage of soybean seed—or other kinds of seed—must understand their effects and interactions as they relate to maintenance of quality.

Inheritance. Soybean seed are inherently short-lived as compared to those of most of the other major agronomic crops (7,9). Corn, wheat, sorghum, and cotton seed all store better than soybean seed under the same environmental conditions (Table 1). Although inherent differences in seed storability among soybean varieties have not been demonstrated, observations and experience indicate that the seed of the older "forage type" soybean varieties stored better than those of the modern "grain type" varieties.

Seed producers and farmers who save seed have learned through experience that successful storage of soybean seed for even one season requires substantial attention to the other three factors that affect storability.

Quality of Seed Entering Storage. The storability of seed is very much influenced by the degree to which the seed have deteriorated prior to storage. Soybean seed subjected to "rainy periods" and warm temperatures prior to harvest, severely damaged during combining, or inadequately aerated during bulk storage do not store well even though germination might be good at the time of packaging (6, 8, 15, 19, 24, 25). The influence of initial quality of the seed on longevity in storage is very evident in the soybean germination data in Table 1 (10). Two groups of four seed lots each (A and B) were stored for 24 months under "warehouse" conditions at Mississippi State University. The four lots of the A group had an initial average germination of 90% and were high in vigor. The four lots of the B group averaged 82% germination at the beginning of storage but were low in vigor as a result of severe weathering before harvest (23). The four B group lots decreased in germination from an

TABLE 1—Comparison of germination percentages of different seed kinds during storage under ambient conditions, Mississippi State University, 1968–1970

Kind of seed	Germination % in:				
	12/68	6/69	12/69	6/70	12/70
Soybeans A	90[a]	91	84	71	33
B	82	68	15	0	0
Corn	98	98	98	97	90
Wheat	94	95	94	90	82
Cotton	87	83	86	83	74
Sorghum	94	91	92	90	82

[a]Each datum represents average germination percentage of four "commercial" seed lots of each kind.

acceptable 80-90% level in December to an unacceptable 60-70% near the end of the planting season (June). The four A group lots, on the other hand, still germinated 90% or better.

Moisture Content and Temperature. The rate of deterioration of seed in storage is greatly influenced by moisture content (5, 13, 17). The higher the moisture content, the more rapidly vigor and germination are reduced. Harrington's "rule-of-thumb" that a 1% decrease in moisture content doubles the storage life of seed holds in a general way for soybeans (6, 17).

The moisture content of soybean seed at harvest ranges from about 9 to 15% depending on the time of harvest (e.g, degree to which the seed have "dried down") and climatic conditions preceding harvest (e.g., rain, dew, relative humidity). Seed harvested above 13% moisture need to be conditioned by aeration/drying to 13% or less as rapidly as possible to minimize deterioration and storage mold problems (4, 7). Normal aeration of seed harvested at 13% or less generally conditions the seed to 11-12% moisture—unless they were harvested at much lower moisture contents—and reduces the temperature.

Soybean seed—as other kinds of seed—are hygroscopic and absorb or lose moisture to the air until an equilibrium between the moisture content of the seed and the relative humidity of the air is established.

The hygroscopic moisture equilibrium values of soybean seed are usually given as follows:

Relative Humidity (%):	30	45	60	65	75	85	90
Seed Moisture Content (%):	6.5	7.4	9.3	—	13.2	—	18.1
				12.5*	14.0*	18.0*	

*Values given by Christensen and Kaufmann (4)

In seed storage studies and practical storage operations, emphasis is most often placed on the controlling influence of relative humidity on seed moisture contents. The hygroscopic equilibrium, however, operates in both directions. The relative humidity within a mass of soybean seed (e.g., in bulk storage bins) harvested at 14-15% moisture will rise to above 75%. And, it will remain at this level regardless of the "outside" relative humidity until the seed are aerated and dried to a lower moisture content. Seed moisture contents in equilibrium with a relative humidity of 75% or higher provide a very favorable environment for the development and reproduction of storage molds, especially during the period immediately following harvest when the seed and ambient temperatures are still relatively warm (4). Prompt and adequate aeration and drying to reduce moisture content of the soybean seed to below 13% is crucial for maintenance of quality.

The storage temperature also has a great influence on maintenance of quality (3, 6, 17). The longevity of seed in storage increases as the temperature decreases. Harrington (17) has dramatized the importance of storage temperature in another "rule-of-thumb": the storage life of seed is doubled for each 10°F decrease in temperature.

In most of the soybean producing areas in the U.S., ambient temperature is decreasing with the changing season during harvest time and becomes quite favorable for storage by November. Seed producers take advantage of this favorable situation and gradually reduce the temperature of the seed in bulk storage or in the warehouse through aeration and ventilation. The importance of low winter temperatures in maintaining soybean seed quality is underscored in the fact that storage problems become progressively more severe from north to south in the U.S. In sub-tropical and tropical countries where there is no distinct "winter" season, maintenance of even a medium level of germination from harvest to the next planting season is almost impossible without conditioned storage facilities (8, 13).

The classic study of Toole and Toole (26) illustrates very well the tremendous effect of seed moisture content and temperature on the longevity of soybean seed in storage (Table 2). Germination of 9.4% moisture seed was maintained for 10 years at 10°C, 5 years at 20°C and only one year at 30°C. At 13.9% moisture, germination decreased below 90% in less than 4 years at 10C, 2 years at 20C, and 6 months at 30C.

Under conditions in Illinois, Holman and Carter (18) found that germination of soybean seed in bulk storage was maintained for 12

TABLE 2—Effect of seed moisture content and temperature on germination percentage of soybean seed during storage

Moisture (%)	Temperature (°C)	Years in storage (approx.)						
		0.5	1	2	3	4	5	10
9.4	10	93	95	98	93	99	92	94
	20	97	99	96	94	89	90	0
	30	96	87	0				
13.9	10	95	98	96	92	88	49	0
	20	98	93	0				
	30	0						

Source: Toole and Toole (26).

months at 10% moisture or less, and through the next planting season (i.e., 7-9 months) at 12 to 12.5% moisture. Germination of seed stored at 13-15% moisture was highly variable and usually unacceptable for planting. Grabe (15, 16) pointed out that the storage life of soybean seed is influenced primarily by moisture content, temperature, and the "prior history" of the seed lot. He recommended that for planting purposes, good sound seed should be stored at no higher than 10% moisture. The seed certification regulations of some states specify a moisture content no higher than 13% for soybean seed (22).

Most of the problems encountered in storing soybean seed for one season, i.e., from harvest to the next planting season, are a result of severe weathering during the harvest period, excessive mechanical damage, and improper aeration or drying when needed. Timely harvesting to minimize field deterioration, adjustment of the combine to minimize damage, and proper aeration and drying virtually eliminates storage problems (7, 8).

Carry-Over and Long-Term Storage

Soybean seed that are not marketed the first planting season after harvest have to be sold as grain or "carried-over" until the next planting season. Carrying-over the seed in inventory involves a total storage period of 19-21 months, which encompasses one full warm season and the beginning of the second.

Germination of good quality seed lots, i.e., germination 80 to 90%, is usually maintained in normal warehouse storage through about August and then drops 5 to 15% or more before the onset of cooler temperatures. As the temperature increases the following spring there is a further decrease in germination. Thus, by the second spring after harvest, the lots usually germinate well below 60% and are unacceptable for planting.

High quality seed lots, i.e., germination 90% or higher, generally maintain their germination in warehouse storage through the summer and well into the fall season in most areas except those along the Gulf Coast. Germination then might decrease a few points in late fall but still hold above 80% through the second marketing season. It might appear, therefore, that carrying-over seed of high quality lots in the upper South and Mid-West is not too difficult. It is not too difficult if the only concern is maintenance of an acceptable level of germination, i.e., 80% or better. The difficulties arise when there is also concern about the vigor of the seed—about how well they will perform when planted.

The vigor of soybean seed decreases much more rapidly than the germination (3, 12). Thus, carried-over soybean seed even though of acceptable germination are frequently so low in vigor that the seed will produce a stand only under very favorable planting conditions. The relationships between loss of germinability and loss of vigor during storage of soybean seed were demonstrated by Byrd and Delouche (3) in studies on deterioration of soybean seed. Their data (Table 3) clearly show that the several vigor indices evaluated decreased much sooner and to a greater extent than germination percentage. Everson (14) has also observed that, "field emergence of carry-over soybean seed lots are sometimes disappointingly low even though the germination tests are high. In this case, the germination test does not reflect the degree of seed deterioration in storage." He advocated use of a modified accelerated aging "stress test" to evaluate the field emergence potential of carry-over seed lots of soybeans.

Discussions with seedsmen reveal a variety of attitudes and experiences in carry-over storage of soybean seed. Most seedsmen do not attempt to carry-over soybean seed save in the most exceptional cases, e.g., very high cost/value seed of a new variety. Some seedsmen regularly carry-over soybean seed stocks but only in conditioned store rooms. A few seedsmen frequently carry-over soybean in normal warehouse storage and apparently experience few difficulties.

Vieira (27) studied the carry-over behavior of seed from 19 "commercial" lots of soybean seed at Mississippi State University in 1974. The lots—from the 1973 crop—were collected in March, 1974, tested and placed in a ventilated warehouse. Thirteen of the lots germinated 90% or better (in March), while the remaining 6 lots germinated between 85 and 89%. The storage performance of the seed lots was as follows:

	No. of seed lots		
Germination range (%)	March	August	December
90% and above	13	5	0
85-89%	6	5	2
80-84%		5	0
70-79%		2	3
60-69%		2	2
Less than 60%			12

Only two of the 19 lots germinated above 80% in December which was still about 5 to 6 months short of the full term of carry-over storage. Over half the lots germinated below 60% in December.

Vieira's experiences with carry-over storage of soybean seed—as cited above—were decidedly on the "bad" side. In other studies we have

TABLE 3—Comparison of results of different quality tests conducted at monthly intervals on soybean seed stored at 30°C.—50% R.H. Source: Byrd and Delouche (7)

Months in storage	First count germ.[a]	Std. germ.[b]	Accel. aging[c]	Heat treatment[d]	Cold test[e]	Growth (3 days)[f]	Field emerg.[g]
0	96	97	93	90	89	41	88
1	94	96	93	88	89	36	86
2	93	95	76*	91	85	38	82
3	95	98	70*	93	76*	35	74*
4	96	99	75*	61*	64*	45	71*
5	88	93	47*	67*	33*	37	50*
6	86	92	29*	56*	13*	36	42*
7	84*	90	30*	10*	3*	21*	31*
8	43*	47*	0*	0*	0*	16*	16*
9	53*	56*	0*	0*	0*	15*	1*
d′.05	9.5	9.4	7.6	5.6	6.4	9.2	9.7
d′.01	12.2	12.0	9.7	7.2	8.1	11.6	12.3
C.V.	7.9%	7.5%	10.4%	7.1%	9.3%	19.9%	11.7%

*Values are significantly different from check (0 months) at 1% level.
[a]% normal seedlings after 4 days under standard test conditions.
[b]% normal seedlings after 7 days under standard test conditions.
[c]Germination % following aging at 42C and 100% r.h. for 48 hrs.
[d]Germination % after immersion of seed in 75C water for 70 seconds.
[e]Emergence % from sand/soil tests incubated at 13C for 5 days followed by 3-4 day period at room temperature.
[f]Length (mm) of root-hypocotyl axis after 4 days at 25C.
[g]Emergence % from field tests planted May 15.

found that 40–50% of initially high quality lots hold germination above 80% during the full term of carry-over storage. While this is better than Vieira's results, the risks are still too great to justify carry-over of soybean seed save under the most exceptional circumstances.

It is evident from the foregoing discussion that carry-over or long-term storage of soybean seed requires something more than initially high quality seed and a ventilated warehouse. There must also be provisions for maintaining moisture content at a low level (10% or less) and moderating the temperature during the warm season periods of storage. The usual provisions are conditioning of the storage environment and/or packaging of the seed in moisture vapor proof packages.

Moisture-Vapor Proof Packaging

High quality soybean seed dried to a moisture content of 9% and packaged in a metal, metal foil, or plastic container impervious to the transmission of moisture vapor will maintain germination for the period of carry-over storage or longer at "open" warehouse temperatures. Andrews (1) stored seed from a good but not high quality lot of Hill soybean in 3-ply multi-wall paper bags with and without a 2 mil polyethylene liner at three initial moisture contents under two temperature regimes. Seed stored at 10°C carried over very well regardless of the packaging material used or the moisture content at the time of packaging (Table 4). The seed packaged in 3-ply multi-wall paper bags with a 2 mil polyethylene liner at 7.2 and 10.4% moisture maintained germination above 80% through the full carry-over period at "warehouse" temperature. Those packaged at 12.8% moisture, however, were drastically reduced in germination by December. None of the seed packaged in 3 ply multi-wall bags without the plastic liner maintained 80% or better germination at open warehouse temperatures. A close examination of the germination data obtained the second December for both packages at warehouse temperature indicates one of the risks involved in moisture-vapor proof packaging. The seed packaged at 12.8% moisture in 3 ply multi-wall bags germinated 57% while those packaged in the multi-wall bag with plastic liner germinated only 18%. For moisture vapor proof packaging of seed, it is essential that the moisture content of the seed be 2 to 3% lower than for ordinary porous or semi-porous packages—less than 10% in the case of soybean.

Packaging of low moisture content seed in moisture vapor proof packages is one means of maintaining a satisfactory level of quality through the carry-over period or even longer. Difficulties and costs associated

Table 4—Effects of initial moisture content, storage condition, and packaging material on germination of soybean seed during storage at Mississippi State University from December 1968 to June 1969

Package	Storage conditions	Initial M.C. (%)	Germination % in:			
			Dec.	Jun.	Dec.	Jun.
Multi-wall, paper	Cold Room[a]	7.2	92	92	88	89
		10.4	90	90	92	89
		12.8	90	92	90	85
	Warehouse[b]	7.2	92	92	86	78
		10.4	92	90	76	59
		12.8	90	92	57	—
Multi-wall paper w/2 mil polyethlene	Cold room[a]	7.2	92	90	93	93
		10.4	90	92	94	94
		12.8	92	90	92	
		12.8	92	90	88	89
	Warehouse[b]	7.2	92	90	91	88
		10.4	92	92	91	83
		12.8	90	90	18	—

Source: Andrews (1).

[a]Cold room maintained at 10°C and 55% relative humidity.

[b]Warehouse of concrete block construction, with insulation in roof, "normal" ventilation.

with this type of packaging, however, have greatly limited its use, especially in high volume field crop seed operations.

Conditioned Storage

A conditioned or controlled seed storage unit is one within which the temperature and/or relative humidity are maintained at specific levels. The purpose of conditioned storage, of course, is to maintain the quality of seed for some period longer than possible without conditioning. Conditioning of a storeroom for relative humidity and temperature requires removal of heat and moisture. These tasks can be efficiently accomplished only in rooms which are specially constructed to retard moisture vapor and heat transfer between the exterior environment and the interior of the room. Major considerations in the selection and design of a conditioned storage facility, therefore, are the type of construction and the material to be stored, thus, the quantity of heat and moisture that have to be removed to maintain design conditions. Detailed discussions of the technical aspects of air conditioning and the design of conditioned storage units have been presented elsewhere (13, 28); therefore, only the major components of a conditioning system are discussed here.

General Construction Features. The main features of conditioned storeroom construction are moisture vapor barriers to prevent or retard to the extent practical, the migration of moisture vapor and transfer of heat from the outside environment into the room. Many different materials are used: plastic film, metal, metal-foil, several types of insulation, paints, asphalt compounds, etc. Frequently, the moisture vapor barriers are an intergal part of the insulation. The quality and quantity of the moisture vapor barrier and insulation required depends on the conditions that are to be maintained in the storeroom, local climatic conditions, and the cost of power. Metal buildings with well caulked seams and sprayed-on insulation (interior) have proven to be quite satisfactory for the conditioning needed for carry-over storage of most kinds of seed including soybean seed. It is important to install vapor barriers and insulation in all parts of the building—walls, ceiling or roof, and the floor. All "openings" for power supply (wiring), plumbing, etc., should be sealed, and the doors should be of metal or metal-clad, tight fitting and gasketed.

Heat Removal. Maintenance of a storeroom temperature lower than the ambient condition requires sufficient air cooling capacity to reduce the temperature of the air and the materials stored in the room (seed) to the design condition, and to maintain it at that level against heat transfer through the walls, ceiling, floor, as well as against the heat released in the room by dehumidification processes, motors, lights, etc. The air conditioning engineer usually evaluates the heat load based on the climatic conditions in the area, the temperature of the incoming seed, quantity of moisture condensed or absorbed in dehumidification, and so on, and then determines the types and quantity of insulation and moisture vapor barriers needed to reduce the heat and moisture loads to economically minimal levels. The temperature needed for carry-over storage of soybean seed—60-65°F maximum—can be attained with "regular" building or room air conditioning equipment. For longer term storage of soybean seed (e.g., breeder and foundation seed), temperatures in the range 40-50°F are required, and can best be achieved with a refrigeration system.

Moisture Removal. An air conditioning system with "high dehumidification" capacity will usually maintain a temperature of 60-65°F and humidity below 60%. These conditions are satisfactory for carry-over storage of soybean seed. In cases where the air-conditioning system will not maintain the relative humidity at 60% or below a condensation-type or desiccant type dehumidifer has to be added to the system. For storage longer than the carryover period, which requires maintenance of humidity below 50%, separate and independent dehumidification (desiccant) and refrigeration systems are generally preferred.

Moisture load calculations need to take into account the expected rate of infiltration of moisture vapor through the walls, doors, ceiling, floor, and the moisture released by the seed as it comes into equilibrium with the relative humidity in the storeroom. Since dehumidification is a heat-releasing process, sufficient air-cooling capacity must be added to compensate for the heat of condensation/adsorption of water vapor.

As mentioned previously, the design of a conditioned storage facility is a very technical subject. Therefore, the services of a competent air-conditioning engineer are required and should be obtained very early in the planning process.

Economic Considerations. The construction of a conditioned warehouse is more costly than for a "regular", ventilated warehouse. The power required for air-cooling and dehumidification, depreciation and maintenance of the conditioning system and building also add greatly to both fixed and operational costs. For these reasons, construction of a conditioned storage facility just for occasional use in carrying-over soybean seed stocks is usually not economical. A conditioned storage facility, however, is economical when high value soybean seed stocks—such as foundation or registered seed—are regularly carried-over, or when the facility is used to carry-over a variety of kinds of seeds including some high-value hybrid and forage seeds. Seedsmen interested in facilities for carry-over storage of soybean seed should carefully examine the costs and benefits.

Summary

Soybean seed are inherently short lived as compared to those of other major crops. Maintenance of an acceptable level of quality for even one season in ordinary warehouse storage is often a problem, especially in the more humid areas of the lower South. High quality soybean seed lots will usually maintain germination above 80% for the full carry-over period under warehouse conditions in the upper South and the Northern regions. The vigor of the seed, however, is often so reduced that the seeds perform poorly in the field except under the most favorable planting conditions.

Maintenance of the quality—germination and vigor—of soybean seed at a satisfactory level during carry-over storage requires: (a) conditioning of the storeroom environment so that it does not exceed 60-65°F and 60% relative humidity; or (b) reduction of the seed moisture content to about 9% and packaging in moisture vapor proof packages, e.g., plastic or plastic/foil laminated bags.

Seedsmen interested in developing facilities or procedures for carry-over storage of soybean seed should carefully analyze the costs and benefits. Conditioned storage is much more costly to construct and operate than ordinary warehouse storage.

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