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Germination of certified soybean seed as influenced by moisture content, length of storage and seasonal temperature fluctuation

Raymond E. Cobble

To the Graduate Council:

I am submitting herewith a thesis written by Raymond E. Cobble entitled "Germination of certified soybean seed as influenced by moisture content, length of storage and seasonal temperature fluctuation." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agriculture and Extension Education.

Robert S. Dotson, Major Professor

We have read this thesis and recommend its acceptance:

L. H. Dickson, L. N. Skold, Henry Andrew

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

May 21, 1960

To the Graduate Council:

I am submitting herewith a thesis written by Raymond E. Cobble entitled "Germination of Certified Soybean Seed as Influenced by Moisture Content, Length of Storage and Seasonal Temperature Fluctuation." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Extension.

Robert S. Dotson
Major Professor

We have read this thesis
and recommend its acceptance:

Leeris H. Dickson

Lawrence V Skold

Henry Andrews

Accepted for the Council:

Dale Wantling
Dean of the Graduate School

GERMINATION OF CERTIFIED SOYBEAN SEED AS INFLUENCED BY MOISTURE CONTENT, LENGTH OF STORAGE AND SEASONAL TEMPERATURE FLUCTUATION

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Raymond E. Cobble

June 1960

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Heartfelt gratitude is extended to my wife, Ernestine, for her love and devotion during the time leading to and including this investigation.

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CHAPTER I

THE PROBLEM AND ASSUMPTIONS MADE

Continuing complaints made by soybean growers and seedsmen alike over a period of years point to the failure of some certified soybean seed to maintain their viability from the date of final certification until planting time. Research in other states showed that soybeans with moisture percentages exceeding 14 per cent will decrease in viability under farm handling and storage conditions when air temperature rises in late spring and early summer months. Experiments disclosed that the factors having the greatest influence on the longevity of soybean seed include the following: 1) seed moisture; 2) length of storage; and 3) temperature. Most of the previous research has dealt specifically with one or another of the three factors listed while the other two were controlled under laboratory-type or pseudo-farm conditions. Similar research has not been done to determine safe moisture percentage levels for farm handling and storage under Tennessee conditions.

I. THE PROBLEM

Statement of the problem. The purposes of the study were as follows: 1) to ascertain whether or not soybean seed having moisture levels above the standard 14 per cent were being certified; and 2) to determine the influence of storage under conditions of seasonal temperature fluctuations on the viability of certified soybean seed having

moisture levels of 14.5 per cent or above at time of final certification.

Importance of the study. Soybeans are grown throughout Tennessee as a hay crop, but commercial production for beans is largely concentrated in the northwestern counties of the state. The acreage harvested for beans increased from 10,000 acres in 1924 to a record high of 250,000 acres in 1955.[1] The Federal-State Cooperative Crop Reporting Service estimated that 276,000 acres of soybeans were harvested for beans from the 1958 Tennessee crop, which is a 15 per cent increase above the ten-year average.[2] The 1958 crop of soybeans harvested for beans was reported to have a farm value of $12,323,000 and to rank fifth among Tennessee crops.[3]

Though soybeans harvested for beans rank fifth in economic importance of all agricultural crops in Tennessee, soybeans vary in ranking from second to third in importance in the ten western counties which produced about ninety per cent of Tennessee's 1958 production as shown in Figure 1.[4]

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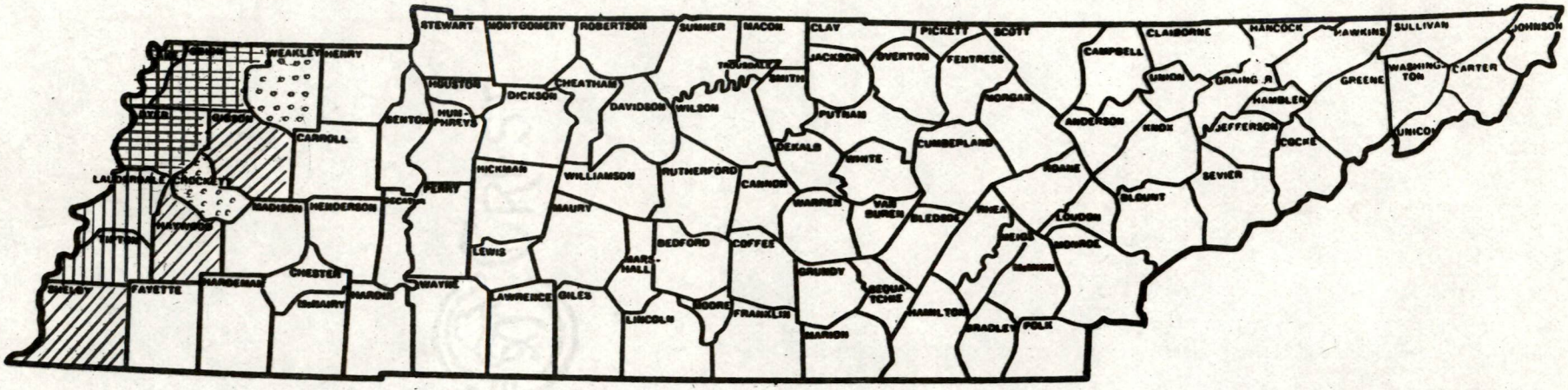
[1] S. T. Marsh, et al., Agricultural Trends in Tennessee, Third Edition (Tennessee Department of Agriculture, Nashville, Tennessee, 1958), p. 80.

[2] S. T. Marsh, et al., Tennessee Soybean County Estimates, 1958 Crop, Federal-State Crop Reporting Service, Release No. 1950 (United States Department of Agriculture, Nashville, Tennessee, 1959), pp. 1-2.

[3] Ibid., pp. 1-2.

[4] Marsh, et al., Tennessee Soybean County Estimates, 1958 Crop, loc. cit.



40,000 to 50,000 Acres

10,000 to 19,999 Acres

20,000 to 39,999 Acres

6,000 to 9,999 Acres

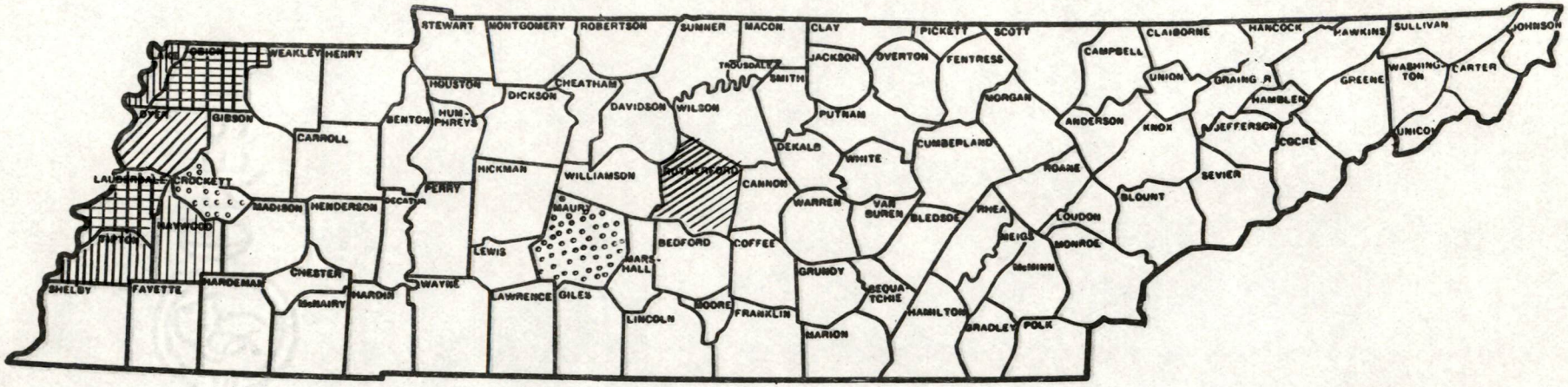
FIGURE 1

THE TEN COUNTIES IN 1958, THAT PRODUCED 90 PER CENT OF THE 276,000 ACRES OF SOYBEANS HARVESTED FOR BEANS IN TENNESSEE

During the period of 1940 to 1959, the acreage of Tennessee farm land planted for certified soybean seed production has increased from approximately 1,500 to slightly more than 3,400 acres. This rapid increase in acreage devoted to certified seed production indicates the growing importance of the soybean seed crop to the growers involved and to the seed trade as a whole.

Seven of the ten major soybean producing counties mentioned earlier were among the ten leading counties producing ninety-four per cent of Tennessee's total 3,400 acres of soybeans harvested as certified seed in 1959 as illustrated in Figure 2.

Concerning the problem of decreased viability of certified soybean seed found by growers in the state, the Tennessee Seed Certification Requirements and Standards as early as 1947 stated that the maximum moisture percentage permissible for certified soybean seed shall be 14 per cent. Seed not meeting this requirement were and are subject to rejection. Until the present time the Seed Certification Committee of the Tennessee Crop Improvement Association has not recommended enforcement of the moisture requirement for a number of reasons, including the following: 1) the lack of research to establish the application of the 14 per cent standard to Tennessee farm handling and storage conditions; 2) the former relatively minor importance of soybeans as a crop in its beginning stages of development in Tennessee; and 3) the lack of information concerning the moisture levels of seed being certified for comparison with its viability at or near planting time (varying in Tennessee from about the last week in April to the second week in July).



700 to 1,000 Acres

100 to 199 Acres

200 to 399 Acres

75 to 99 Acres

FIGURE 2

THE TEN COUNTIES IN 1959, THAT PRODUCED 94 PER CENT OF THE 3,400 ACRES OF CERTIFIED SOYBEAN SEED IN TENNESSEE

II. THE ASSUMPTIONS

Statement of assumptions made. For purposes of the study, certain assumptions were made as follows:

1) Dried samples in cloth bags were used to simulate optimum farm storage conditions.

2) Undried samples (14.5 per cent moisture and above) in polyethylene bags were used to simulate extremely undesirable farm storage conditions.

3) Had samples been left as a check group in open basement storage, viability would have continued to be relatively unaltered by length of storage (seasonal temperature fluctuation) until the last test date of June 16, 1958.

4) Third-floor storage of samples during the final ten days of storage was imposed to simulate seasonal temperature fluctuations in transit, on seed store floors, and in farm storage for the period prior to actual planting.

5) Had samples of seed containing less than 14.5 per cent moisture been included in final treatments and tests, viability would have remained relatively unchanged by length of storage and temperature fluctuation.

   a) With the additional assumption that moisture picked up by seed in cloth bags would not have been sufficient to take the moisture level above the specified danger point of 14.5 per cent (because of high relative humidity of storage air).

The foregoing assumptions were made in an effort to simulate farm storage and handling conditions as nearly as possible.

CHAPTER II

REVIEW OF THE LITERATURE

Preservation of viability in seed by control measures has been of interest to people since ancient times. Among various techniques used by man through the years were application of preservative materials and control of: 1) seed moisture; 2) storage temperature; and 3) storage relative humidity. According to Dju and McCay, the ancient Indian method of storing beans coated with castor oil or wood ashes was found to favor slightly the preservation of vigor and viability of soybeans kept at room temperature.[1] However, the literature reviewed herein will be primarily limited to that dealing specifically with seed moisture, length of storage and temperature.

I. LITERATURE ON VIABILITY OF STORED SOYBEAN SEED UNDER CONTROLLED CONDITIONS

Ramstad and Geddes of Minnesota, using soybeans of various moisture content sealed in glass jars and stored at room temperature noted an increased rate of loss in germination as the moisture content was raised from 9.4 to 19.1 per cent. None of the samples with moistures in excess

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[1]Dju, Dsai and C. McCay, "Vigor and Viability in Soybeans," Soybean Digest, 9:22, June, 1949.

of 13.8 per cent were viable after three and one-half months storage.[2]

Robbins and Porter reported that soybeans with a moisture content of 30 to 32 per cent or less was not reduced in viability by freezing for ten hours at -20 degrees Fahrenheit.[3] Therefore, we would not expect low temperature to reduce germination of soybeans under Tennessee storage conditions.

Brewer and Butt found initial seed viability of natural and artificially dried lupine seed (legume) to be the property of greatest importance for determining safe storage humidities under conditions of their experiments.[4] Therefore, seed of highest initial viability showed the least decrease in viability at relative humidity levels of 25 to 65 per cent in an eight-week storage test.

Toole and Toole conducted studies at Beltsville, Maryland, using North Carolina grown seed to measure the interrelationship of temperature and moisture of soybean seed in storage.[5] Seed samples having moisture

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[2]Paul E. Ramstad and W. F. Geddes, The Respiration and Storage Behavior of Soybeans (University of Minnesota Agricultural Experiment Station, Technical Bulletin 156, St. Paul, Minnesota, 1942), p. 26.

[3]Wayne A. Robbins and R. H. Porter, "Germinability of Sorghum and Soybean Seed Exposed to Low Temperatures," Journal of the American Society of Agronomy, 38:912, October, 1946.

[4]H. E. Brewer and J. L. Butt, "Hygroscopic Equilibrium and Viability of Natural Dried Blue Lupine Seeds," Plant Physiology, 25:267, February, 1950.

[5]E. H. Toole and V. K. Toole, Relation of Temperature and Seed Moisture to the Viability of Stored Soybean Seed, United States Department of Agriculture, Circular 753 (Washington: Government Printing Office, 1946), p. 2.

percentages of 18.1, 13.9 and 9.4 were sealed in glass jars and placed in storage chambers in February 1934, with temperatures maintained at 86, 68, 50 and 36 degrees Fahrenheit.[6] Seed of 18.1 per cent moisture lost viability extremely rapidly the first month of storage at 86 degrees, but maintained good germination for five months at lower storage temperatures as shown in Table I.[7] Seed of 13.9 per cent natural moisture lost viability rapidly after three months of storage at the relatively high temperature of 86 degrees Fahrenheit, but maintained good germination for five months at lower storage temperatures as shown in Table II.[8] Seed of 9.4 per cent moisture maintained good germination for five months at all four temperature storage levels as shown in Table III.[9]

Humphries and Hurst found that the relative humidity of the atmosphere governs the moisture content of soybeans to a greater extent than air temperature.[10]

J. F. Harrington attributes high moisture content of seed as being the greatest single cause of loss of germination.[11] The amount

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[6] Ibid.

[7] Ibid., p. 4.

[8] Ibid.

[9] Ibid.

[10] W. R. Humphries and W. M. Hurst, "Moisture Change in Some Agricultural Products Due to Atmospheric Conditions," Agricultural Engineering, 16:9, January-December, 1935.

[11] J. F. Harrington, Drying, Storing, and Packaging Seeds to Maintain Germination and Vigor, Proceedings of Short Course for Seedsmen (Seed Technology Laboratory, State College, Mississippi, 1959), p. 89.

TABLE I

GERMINATION OF SOYBEANS CONTAINING 18.1 PER CENT MOISTURE STORED FEBRUARY 1, 1934, AT DIFFERENT TEMPERATURES[a]

Date of germination	Storage temperatures			
	86°	68°	50°	36°
March 13, 1934	14	93	97	--
May 3, 1934	0	96	91	94
June 6, 1934	0	94	96	94
July 10, 1934	0	85	96	98

[a]From E. H. Toole and V. K. Toole, Relation of Temperature and Seed Moisture to the Viability of Stored Soybean Seed, United States Department of Agriculture, Circular 953 (Washington: Government Printing Office, 1946), p. 4.

TABLE II

GERMINATION OF SOYBEANS CONTAINING 13.9 PER CENT MOISTURE STORED FEBRUARY 1, 1934, AT DIFFERENT TEMPERATURES[a]

Date of germination	Storage Temperatures			
	86°	68°	50°	36°
March 13, 1934	98	99	97	---
May 3, 1934	87	99	96	97
June 6, 1934	40	97	91	96
July 10, 1934	0	98	95	94

[a]From E. H. Toole and V. K. Toole, Relation of Temperature and Seed Moisture to the Viability of Stored Soybean Seed, United States Department of Agriculture, Circular 753 (Washington: Government Printing Office, 1946), p. 4.

TABLE III

GERMINATION OF SOYBEANS CONTAINING 9.4 PER CENT MOISTURE STORED FEBRUARY 1, 1934, AT DIFFERENT TEMPERATURES[a]

Date of germination	Storage temperatures			
	86°	68°	50°	36°
March 13, 1934	--	--	--	--
May 3, 1934	97	96	96	98
June 6, 1934	98	95	94	98
July 10, 1934	96	97	93	94

[a]From E. H. Toole and V. K. Toole, Relation of Temperature and Seed Moisture to the Viability of Stored Soybean Seed, United States Department of Agriculture, Circular 753 (Washington: Government Printing Office, 1946), p. 4.

of moisture in seeds affects many processes which Harrington summarized as follows:

Seed Moisture above 45-60%--Germination occurs
Seed Moisture above 18-20%--Heating may occur
Seed Moisture above 12-14%--Molds grow on and in seed
Seed Moisture below 8- 9%--Little or no insect activity
Seed Moisture below 4- 8%--Sealed storage is safe.[12]

Harrington also supported the finding of Humphries and Hurst that the moisture content of a given seed depends on the relative humidity, temperature having little affect on it. If the relative humidity of the air around the seed rises, the seed moisture will rise as shown in Table IV.[13] In Table IV, it can be observed that crop seeds high in oil have a lower moisture content in equilibrium with the same per cent relative humidity than crop seeds high in starch and low in oil. The only exception being soybeans which absorbed moisture at more rapid rate at 90 per cent relative humidity than at lower levels.[14]

II. LITERATURE ON VIABILITY OF STORED SOYBEAN SEED UNDER UNCONTROLLED CONDITIONS

Oathout, who studied the longevity of soybean seed in Illinois, reported that under uncontrolled air temperatures seed moisture generally stabilized between ten to fourteen per cent regardless of the moisture at

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[12] Ibid., p. 90.

[13] Ibid., p. 91.

[14] J. F. Harrington, Drying, Storing, and Packaging Seeds to Maintain Germination and Vigor, Proceedings of Short Course for Seedsmen (Seed Technology Laboratory, State College, Mississippi, 1959), p. 91.

TABLE IV

ABSORBED MOISTURE CONTENT OF FIELD SEED IN EQUILIBRIUM WITH AIR OF VARIOUS RELATIVE HUMIDITIES AT ROOM TEMPERATURE (APPROXIMATELY 77 DEGREES FAHRENHEIT, MOISTURE CONTENT GIVEN ON A WET BASIS IN PER CENT)[a]

Field crop seed	Relative humidity, per cent						
	15	30	45	60	75	90	100
Barley	6.0	8.4	10.0	12.1	14.4	19.5	26.8
Shelled corn, YD	6.4	8.4	10.5	12.9	14.8	19.1	23.8
Shelled corn, WD	6.6	8.4	10.4	12.9	14.7	18.9	24.6
Flaxseed	4.4	5.6	6.3	7.9	10.0	15.2	21.4
Oats	5.7	8.0	9.6	11.8	13.8	18.5	24.1
Peanuts	2.6	4.2	5.6	7.2	9.8	13.0	--
Rye	7.0	8.7	10.5	12.2	14.8	20.6	26.7
Sorghum	6.4	8.6	10.5	12.0	15.2	18.8	21.9
Soybeans	4.3	6.5	7.4	9.3	13.1	18.8	--
Wheat (soft red winter)	6.3	8.6	10.6	11.9	14.6	19.7	25.6
Wheat (hard red winter)	6.4	8.5	10.5	12.5	14.6	19.7	25.0

[a]From J. F. Harrington, Drying, Storing, and Packaging Seeds to Maintain Germination and Vigor, Proceedings of Short Course for Seedsmen (Seed Technology Laboratory, State College, Mississippi, 1959), p. 91.

the beginning of storage.[15] Seed of the 1925 crop having a 15.1 per cent moisture and a germination of 92 per cent stored in an open four foot deep bin maintained their viability of 89 per cent at the top and 88 per cent at the bottom until after the following seed planting season. Seed of the same lot stored in sacks, with abundant provisions for natural circulations of air, maintained their viability of 84 per cent until March 10, 1927, of the second planting season, while bin stored seed declined in viability to 45 per cent in top of bin and 25 per cent in bottom of bin on this date.

Robertson and Lute reported seeds of Wisconsin Black soybeans stored in sacks in a dry unheated room in Colorado maintained their viability for the first five years, while germination of wheat, oats and barley dropped only slightly the first ten years. Corn maintained viability for five years and cane for seventeen years.[16] This study showed that the arid climatic conditions of Colorado were favorable to maintenance of viability of soybean seed as well as other crop seeds used in their experiment.

Carter and Holman conducted research work at the Illinois station on soybean storage in farm type bins. They found that soybeans

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[15] C. H. Oathout, "The Vitality of Soybean Seed as Affected by the Storage Conditions and Mechanical Injury," Journal of the American Society of Agronomy, 20:844, August, 1928.

[16] D. W. Robertson, et al., "Germination of Twenty Year Old Wheat, Oats, Barley, Corn, Rye, Sorghum and Soybeans," Journal of the American Society of Agronomy, 35:795, September, 1943.

stored at 14 to 15 per cent moisture through late fall and winter lost very little quality, but serious deterioration began when the weather warmed up.[17] The market crop can be stored at moistures 13 to 14 per cent from fall until the following late spring or early summer. Germination test should be made on such beans just before planting. Soybeans stored at moistures of 12 to 13 per cent are generally safe for at least a year's storage with little loss in germination. In tests, the market grade did not go down until after the second year. Soybeans stored at moistures below 12 per cent are safe from trouble due to moisture content at time of storage. Beans may pick up some moisture, and some accumulation can be expected in the upper part of the bin during the winter. Germination was maintained until well into the second year. Market beans at ten per cent moisture were held for nearly four years in farm type bins without a reduction in grade.[18]

Burlison, Van Doren and Hackleman stored soybeans of 11.1 per cent moisture in a crib under Illinois farm conditions and found that possible germination was maintained at all crib levels from October 25, 1929, to July 8, 1930.[19] Highest moisture content during the

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[17]Dean G. Carter and Leo E. Holman, Storing Soybeans on the Farm (University of Illinois Agricultural Extension Service, Circular 692, Urbana, Illinois, 1952), p. 5.

[18]Ibid.

[19]W. L. Burlison, et al., Eleven Years of Soybean Investigations (University of Illinois Agricultural Experiment Station, Bulletin 462, Urbana, Illinois, 1940), p. 154.

period was 13.2 per cent at the one-foot level below the surface and lowest germination of 84 per cent was reported at the surface on July 8, 1930. Test of the same seed on August 1, 1931, showed that germination down to the two-foot level had dropped to 50 per cent and moisture increased to 14.2 per cent. Seed at three and four-foot levels still germinated around 90 per cent with moisture ranging from 11.0 to 12.5 per cent.

Hartwig reported that:

> Seed stored in several different types of structures at the Delta Branch Experiment Station over the past several years have consistently maintained their germination when these samples were harvested with care and put in storage with a moisture content of 13 per cent or less.[20]

III. LITERATURE ON MECHANICAL INJURY AND TIME OF PLANTING AS RELATED TO VIABILITY OF SOYBEAN SEED

The following review of literature relates to conditions of seed quality which may contribute to the reduction in germination of soybean seed in storage. The influence of seed quality was not measured in this study.

Moore reported very little relationship between total germination and the per cent of mechanically injured seed by laboratory test.[21]

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[20] Edgar E. Hartwig, "Saving Top Quality Soybean Seed" (Stoneville, Mississippi: United States Regional Soybean Laboratory and Delta Branch Experiment Station, 1958) (Mimeographed), p. 3.

[21] R. P. Moore, "Harvest with Care," North Carolina Agricultural Experiment Station publication, Research and Farming, 15:3, Summer, 1956.

Comparison of germination in sterile soil and in field test showed a direct relationship between per cent emergence and degree of seed coat injury.[22]

Humphrey reported relatively little damage in germination to Lee soybeans at 11.2 per cent moisture when run through the cleaner twice. However, beginning with the third cleaning the beans were seriously damaged.[23]

Hartwig reported that whenever a high percentage of split soybeans result from harvesting, there are many other beans that are injured which will not produce vigorous sprouts.[24] The soybeans are more easily injured as the seed moisture decreases (See Table V).[25] A seed moisture range of 10 to 13 per cent is a safe range for handling and storing good quality planting seed while operating the combine cylinder at the slowest speed to do a good job of threshing.[26]

Time of planting studies conducted at the Mississippi Delta Branch Experiment Station have shown that May plantings of soybeans consistently give higher seed yields and produce higher germinating seed than earlier

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[22] Ibid., p. 3.

[23] L. M. Humphrey, "Soybean Germination: The Effects of Cleaning," Soybean Digest, 8:22, August, 1948.

[24] Hartwig, op. cit., p. 1.

[25] Ibid.

[26] Ibid.

TABLE V

INFLUENCE OF MOISTURE CONTENT OF SEED UPON GERMINATION AND PER CENT BREAKAGE WHEN THRESHED[a]

Moisture content at harvest	Germination of hand threshed sample	Germination of threshed sample	Per cent breakage in threshing
8.1	97	87	13
10.4	99	97	8
12.2	99	97	4
13.7	98	96	2
16.1	98	94	1

[a]From Edgar E. Hartwig, "Saving Top Quality Soybean Seed" (Stoneville, Mississippi: United States Regional Soybean Laboratory and Delta Branch Experiment Station, 1958) (Mimeographed), p. 1.

plantings.[27]

IV. LIMITATIONS OF PREVIOUS STUDIES

The results of studies in the review of literature on the interrelationship of soybean seed viability, moisture and temperature which were conducted under laboratory controlled conditions would be most applicable to seed storage conditions where either or both the moisture or temperature may be controlled. Information from these studies may also be applied in areas where either one or both the temperature and relative humidity remain at consistent levels for a given period of time. However, these data are useful only for general application to soybean seed in open air storage in Tennessee, where wide fluctuations in relative humidity and temperature exist throughout the year.

Studies of soybean seed viability under uncontrolled temperature and moisture conditions have been conducted in other states where temperature, humidity and storage methods are not representative of Tennessee. The farm storage studies were conducted with seed held throughout the experiment in bin type storage in areas where bin sampling for certification is practiced. In Tennessee, certified soybean seed are removed from bin type storage during the winter months to be processed and bagged before samples are drawn for certification.

In summarizing previous investigations, it is clear that there is insufficient research data available which is applicable to Tennessee

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[27] Ibid., p. 1.

climatic conditions or seed handling methods to justify the enforcement of the 14 per cent maximum moisture allowable for Tennessee certified seed.

CHAPTER III

METHODS OF PROCEDURE

Tennessee seed certification inspectors drew a representative sample from each lot of bagged seed of the 1957 crop for seed analysis as a prerequisite to final certification. A total of 80 lots of seed were represented. One-half of each official sample was placed by the inspector in the standard cloth bag presently used for certified seed samples. This portion of the sample was then directed to one of the three approved private seed testing laboratories in Tennessee for analysis. All three of these laboratories participated in making the first complete analysis except for moisture. The samples were analyzed by these laboratories for purity, other crop seeds, other varieties, common and noxious weed seeds, and germination. Data obtained were sent to the Tennessee Crop Improvement Association.

The other one-half of each original official sample was placed by the inspector in a moisture resistant polyethylene bag of 1.5 mm. thickness and sent to the Tennessee Crop Improvement Association headquarters in Nashville. These samples were held in cool open-air storage until moisture analysis was made by the "Steinlite" moisture tester technique. Twenty-one of the test samples had moisture levels of 14.5 per cent and above and each was sub-divided into two equal parts for further study.

I. CLASSIFICATION OF TEST SUB-SAMPLES

The first part of the twenty-one test sub-samples, referred to as Group A in the remainder of the thesis, was air-dried at room temperature to approximately 8 to 10 per cent moisture and placed in cloth bags for storage under open-air conditions. The second part, also consisting of twenty-one sub-samples, referred to as Group B in the remainder of the thesis, was placed immediately in moisture resistant polyethylene bags which were then tightly closed and sealed with rubber bands for open-air storage.

II. DEFINITION OF TERMS

For purposes of use in the remainder of this thesis, it will be convenient to define three terms at this point:

1) Reduced moisture content shall henceforth refer to the moisture content contained in Group A sub-samples as dried at room temperature to approximately 8 to 10 per cent moisture.
2) Natural moisture content shall henceforth refer to the moisture content contained in the seed at the time of sampling.
3) Germination tolerance shall henceforth refer to the percentage in variation permitted between the germination results of two consecutive analyses of representative samples of the same seed.

III. EXPLANATION OF TREATMENTS

Analysis dates for the foregoing procedure (stage 1), prior to final certification, ran from February 25 through April 15, 1958. This investigation, then, concerned a total of twenty-one matched pairs of samples broken into forty-two separate sub-samples for study purposes.

Stage 2, the first test after storage, consisted of moisture and germination analyses to determine effects of storage. These moisture and germination analyses were made between May 5 and June 5, 1958, after a minimum of forty-nine days in storage.

In stage 3, the forty-two sub-samples were moved on June 5, 1958, from the first floor to the third floor of a five-story brick building where they were held in open-air storage until June 16.

Stage 4, the second and final test stage after storage, consisted of moisture and germination analyses to determine what further changes were taking place after a minimum of eleven days third-floor open-air storage. The moisture analyses were made on June 16 and seed of each sample placed in germinators on the same date.

Local temperature and humidity data with comparative data covering the time of this study are given in Table VI.[28]

The investigation was carried out in the Tennessee Crop Improvement Association seed testing laboratory. Moisture and germination analyses

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[28] United States Department of Commerce, Weather Bureau, Local Climatological Data; Nashville, Tennessee: 1958 (National Weather Records Center, Asheville, North Carolina, 1959), pp. 1-4.

TABLE VI

AVERAGE MONTHLY TEMPERATURE AND PER CENT HUMIDITY FOR 1958, AND MEAN TEMPERATURE AND MEAN HUMIDITY FOR TOTAL PERIOD RECORDED FOR NASHVILLE AREA[a]

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1958 Average temperature	35.4	31.0	44.0	58.4	68.2	75.0	80.1	77.7	71.8	59.6	51.7	36.2	57.4
Mean temperature for period recorded	39.4	41.3	49.7	59.4	68.3	76.4	79.5	78.4	72.3	61.0	48.9	41.3	59.6
1958 Average per cent relative humidity	76	70	76	71	74	70	78	77	75	76	72	71	72
Mean per cent relative humidity for period recorded	76	71	67	66	65	68	69	71	69	68	69	74	69

[a]From United States Department of Commerce, Weather Bureau, Local Climatological Data; Nashville, Tennessee: 1958 (National Weather Records Center, Asheville, North Carolina, 1959), pp. 1-4.

using techniques prescribed in the United States Department of Agriculture's Manual for Testing Agricultural and Vegetable Seeds, were made with the assistance of Tennessee Crop Improvement Association personnel, who are experienced in seed analysis.[29]

IV. SELECTION OF STATISTICAL TECHNIQUES

Correlation regression for statistical analyses as outlined by George W. Snedecor was used for evaluating these data.[30] The 1 per cent level of confidence was selected for use in the study.

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[29] United States Department of Agriculture, Manual for Testing Agricultural and Vegetable Seeds, Agricultural Handbook No. 30 (Washington: Government Printing Office), pp. 146-158.

[30] George W. Snedecor, Statistical Methods, Fourth Edition (Ames: The Iowa State College Press, 1946), pp. 103-168.

CHAPTER IV

EXPERIMENTAL RESULTS

The moisture content of official certified soybean samples collected during the period February 25, 1958, through April 16, 1958, are summarized in Table VII. As shown in this table, 39 or 54 per cent of the seventy-two samples contained 14 per cent moisture or less. Of the remaining thirty-three samples, 46 per cent of the total number exceeded the 14 per cent certification moisture standard allowable. On visual inspection there does not appear to be any correlation between high seed moisture and low germination per cent at the time of sampling as shown in Table VII. Seed samples in the low moisture range of 11.0 to 12.9 per cent were found to germinate between 90 and 95 per cent, while samples in the high moisture range of 17.0 to 17.6 per cent were found to germinate between 90 and 92 per cent.

Eight of the eighty certification samples failed to meet the minimum germination standard of 80 per cent. A list of the reasons why the samples were of such low germination would apparently include: 1) moisture levels in excess of the standard allowable; 2) mechanical injury due to improper care at harvesting time; 3) injury due to improper handling before sampling, and 4) exposure to high temperature during previous storage immediately after harvesting.

The Group A sub-samples maintained germinations of 80 per cent and above on the first analysis after a minimum of forty-nine days in storage with the exception of one sub-sample. The single exception

TABLE VII

THE RELATIONSHIP OF MOISTURE AND GERMINATION PERCENTAGES OF 72 CERTIFIED SEED SAMPLES MEETING MINIMUM GERMINATION REQUIREMENTS OF 80 PER CENT[a]

Number of samples	Per cent of total samples	Per cent moisture range	Per cent germination range
9	12	11.0-12.9	90-96
30	42	13.0-14.0	80-96
12	17	14.1-14.4	84-96
7	10	14.5-14.9	84-95
7	10	15.0-15.9	82-95
4	5	16.0-16.9	82-92
3	4	17.0-17.6	90-92

[a]Eight of the original 80 samples collected did not meet the minimum certification germination standard of 80 per cent.

declined to 75 per cent after registering natural moisture content of 16.4 per cent as shown in columns 1 and 4, Table VIII. In comparison, five of Group B sub-samples which had retained moisture percentages of 14.6, 14.3, 15.5, 15.9 and 16.8 declined in germination percentages to 63, 74, 60, 51 and 76, respectively, as shown in columns 7 and 8 of Table VIII. Study of the data shows that these five Group B sub-samples declined below 80 per cent germination. They represent 36 per cent of the Group B sub-samples and retained moistures of 14.3 per cent and above at the time of the first analysis after storage was imposed.

On the last analysis date, June 16, 1958, following a minimum of sixty-two days in storage for all sub-samples, all of the Group A sub-samples (representing very favorable storage) maintained germination percentages above 80 per cent with the exception of three of the sub-samples. This is shown in column 6 of Table VIII. These three sub-samples having germination percentages of 76, 74 and 76 had original moisture percentages of 16.3, 16.4 and 17.6, respectively. On the last analysis date of June 16, only six or approximately 30 per cent of the Group B sub-samples (representing unfavorable farm storage) maintained germination percentages above the minimum certification requirement of 80 per cent (See column 10 of Table VIII). The six Group B sub-samples maintaining germination of 80 per cent and above included all of the samples with natural moisture content of 14.5 to 14.9 per cent except for one sub-sample of 14.7 per cent. This latter sub-sample declined to a low germination of 55 per cent. In comparing the sub-sample above with the six sub-samples maintaining 80 per cent germination,

TABLE VIII

MOISTURE AND GERMINATION PERCENTAGES OF SELECTED SAMPLES OF SOYBEAN SEED CERTIFIED IN 1958, PRIOR TO AND FOLLOWING STORAGE FOR SPECIFIED TIME PERIODS UNDER DIFFERENT STORAGE CONDITIONS

ORIGINAL SAMPLES[a] Tests conducted prior to storage on April 16		GROUP A SUB-SAMPLES[b]				GROUP B SUB-SAMPLES[c]			
		April 16 - June 5 Storage period[d]		June 5 - June 16 Storage period[e]		April 16 - June 5 Storage period[d]		June 5 - June 16 Storage period[e]	
Moisture per cent	Germination per cent	Moisture per cent	Germination per cent	Moisture per cent	Germination per cent	Moisture per cent	Germination per cent	Moisture per cent	Germination per cent
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
14.5	90	9.2	87	8.8	88	13.4	89	13.0	85
14.6	85	10.0	95	8.2	93	13.7	84	12.4	80
14.7	95	8.6	91	9.1	98	14.0	91	13.4	92
14.7	91	11.0	96	8.0	92	13.4	96	12.0	87
14.7	84	8.6	84	8.8	83	14.6	63	14.1	55
14.9	92	7.9	88	8.2	92	14.6	90	13.3	84
14.9	91	8.7	90	8.3	87	14.0	93	13.5	82
15.0	91	8.6	86	8.9	92	14.9	84	14.3	79
15.0	86	10.4	87	8.0	84	11.8	86	9.4	76
15.2	95	8.8	94	8.9	97	15.0	93	14.5	76
15.3	82	9.6	84	8.9	84	14.3	74	13.3	71
15.3	84	10.8	88	8.2	81	14.3	80	13.4	61
15.7	88	10.2	91	8.2	89	14.0	91	12.8	75
15.8	88	11.5	84	7.9	89	14.7	83	14.0	65
16.1	90	9.2	88	8.0	91	15.4	89	14.8	69
16.3	82	8.4	81	8.2	76	15.5	60	14.0	48
16.4	92	9.8	91	8.2	90	15.9	93	14.9	68
16.4	92	8.0	75	8.3	74	15.9	51	15.3	23
17.2	92	10.7	80	8.0	83	16.7	82	16.0	14
17.2	90	10.4	87	8.2	86	16.3	82	15.4	25
17.6	90	10.7	84	7.9	76	16.8	76	15.7	7

[a]Original complete samples taken at time of certification. Includes Group A and Group B sub-samples together.

[b]Portion of original samples air-dried to 8 to 10 per cent moisture and stored in cloth bags in open air.

[c]Portion of original samples placed in polyethylene bags at sampling time and stored with Group A sub-samples.

[d]Conditions simulated normal winter and spring bagged storage and handling in Tennessee.

[e]Conditions simulated normal late spring and early summer bagged storage and handling in Tennessee.

the six sub-samples declined in moisture content within the range of 12 to 13.5 per cent, while the sample with the 55 per cent germination retained a moisture of 14.1 per cent. All of the natural moisture samples with retained moistures of 14.0 and above on June 16 had declined below 80 per cent germination, as shown in column 10, Table VIII.

A comparison was made of the germination of Group A and Group B soybean sub-samples. Results are summarized in Figure 3. The Group A sub-samples maintained their viability above minimum germination standard of 80 per cent with the exception of three sub-samples. These three sub-samples, having germination percentages of 76, 74 and 76, originally contained moistures of 16.3, 16.4 and 17.6, respectively, as shown in Figure 3.

Only six Group B sub-samples maintained minimum germination requirements. These six sub-samples had original moisture contents ranging from 14.5 to 14.9 per cent. At the same time, however, one sub-sample within this original moisture range (14.5 to 14.9 per cent) declined in viability from 84 to 55 per cent.

The other fourteen sub-samples in Group B, which declined below 80 per cent germination, lost viability extremely rapidly as their original moisture content increased from 15.0 to 17.4 per cent.

When the means of the original moisture percentages and final germination percentages of Group B sub-samples were compared, it was learned that the correlation ($r = -0.88$) was highly significant, as shown in Table IX.

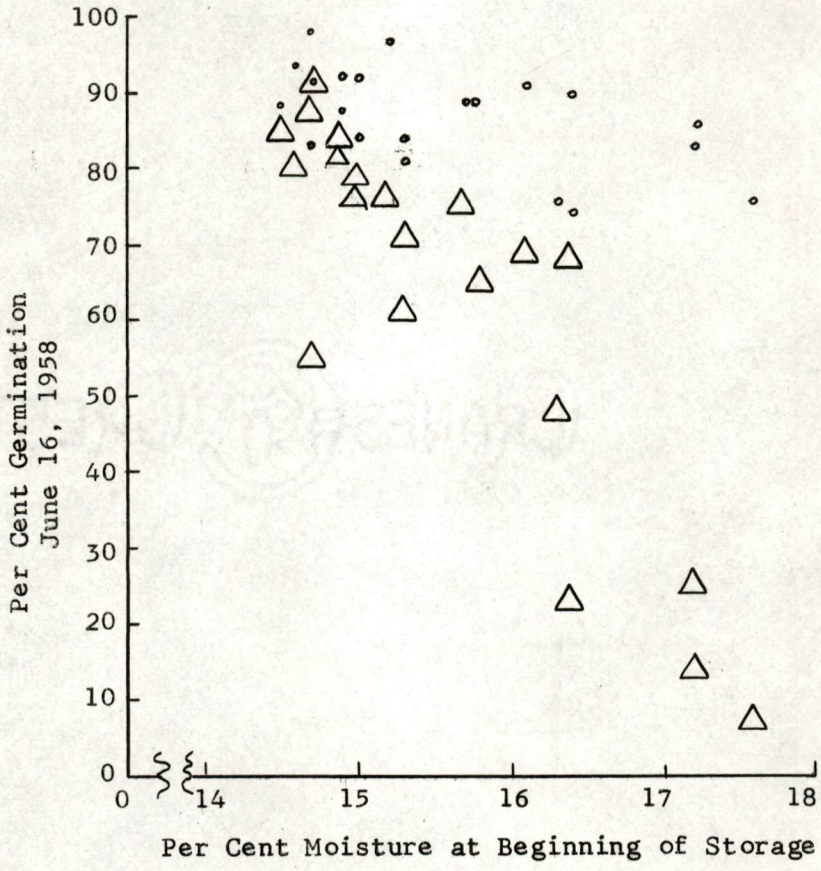

FIGURE 3

COMPARISON OF GERMINATION PERCENTAGES OF GROUP A AND GROUP B SUB-SAMPLES AFTER FINAL STORAGE PERIOD JUNE 16, 1958, BASED ON NATURAL MOISTURE CONTENT

TABLE IX

MOISTURE AND GERMINATION MEANS AND PERCENTAGES OF GROUP B SUB-SAMPLES, PRIOR TO AND FOLLOWING STORAGE AND HANDLING TREATMENTS

Sample number	Tests conducted prior to storage on April 16		Tests conducted after storage on June 16	
	Moisture per cent	Germination per cent	Moisture per cent	Germination per cent
(1)	(2)	(3)	(4)	(5)
4070	14.5	90	13.0	85
5054	14.6	85	12.4	80
3036	14.7	95	13.4	92
6018	14.7	91	12.0	87
4069	14.7	84	14.1	55
5083	14.9	92	13.3	84
5036	14.9	91	13.5	82
6027	15.0	91	14.3	79
5052	15.0	86	9.4	76
3040	15.2	95	14.5	76
5045	15.3	82	13.3	71
5049	15.3	84	13.4	61
5051	15.7	88	12.8	75
6013	15.8	88	14.0	65
5034	16.1	90	14.8	69
5048	16.3	82	14.0	48
5035	16.4	92	14.9	68
6006	16.4	92	15.3	23
6011	17.2	92	16.0	14
6017	17.2	90	15.4	25
6012	17.6	90	15.7	7
Mean	15.6		13.8	63 **

** Significant at the 1% level of confidence for both the correlation between (2) and (5), and (4) and (5).

Further analyses of the means of the first moisture percentages with the final germination percentages of the Group B sub-samples disclosed that the correlation again was highly significant ($r = -0.67$).

Comparison of the means of the original moisture percentages of the Group A sub-samples with the final germination percentages showed that the correlation ($r = -0.54$) was not significant at the level of confidence selected for the study. It was, however, significant at a lower level of significance.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary. Approximately 46 per cent of the 1957 Tennessee soybean seed crop was certified with moisture content in excess of the allowable 14 per cent moisture standard. If an additional .5 per cent moisture was permitted to compensate for possible errors in sampling and moisture analysis, there would still have been 29 per cent of the soybean seed being certified at 14.5 per cent moisture or more.

Soybean seed with moisture up to 17.6 per cent after being held in farm storage in Tennessee from harvest through the following cold winter months maintained germination from 82 to 96 per cent. Selected sub-samples of this seed continued to maintain good viability until the following June. They had received the following treatment: 1) were removed from farm storage during the winter months; 2) were air-dried to 8 to 10 per cent moisture; and 3) were held in open-air storage for the entire treatment period (April 16 - June 16, 1958). The results obtained have practical application. For instance, if it became necessary to harvest high moisture soybean seed due to unfavorable weather conditions in the late fall, the seed could be stored as harvested and drying could be completed in the winter months. This practice would permit uninterrupted harvesting operation, thereby utilizing labor and machinery more efficiently.

The effects of seasonal temperature fluctuation on the viability of soybean seed containing 14.5 per cent moisture or above, when stored under reduced and natural moisture content as conducted in this study, are dependent upon certain assumptions. Assumptions were made in an effort to reproduce conditions as nearly similar to farm storage and handling conditions as possible. The assumptions were as follows:

1) Air-dried samples in cloth bags (Group A sub-samples in the study) were used to simulate optimum farm storage conditions.
2) Undried samples (14.5 per cent moisture and above) in polyethylene bags (Group B sub-samples in the study) were used to simulate extremely undesirable farm storage conditions.
3) Had samples been left as a check group in open basement storage, viability would have continued to be relatively unaltered by length of storage (seasonal temperature fluctuation) until the last test date of June 16, 1958.
4) Third-floor storage of samples during the final ten days of storage simulated seasonal temperature fluctuations in transit, on seed store floors, and in farm storage for the period prior to actual planting.
5) Had samples of seed containing less than 14.5 per cent moisture been included in final treatments and tests, viability would have remained relatively unchanged by length of storage and temperature fluctuation.

a) With the additional assumption that moisture picked up by seed in cloth bags (because of high relative humidity of storage air) would not have been sufficient to take the moisture level above the specified danger point of 14.5 per cent.

All of the Group B sub-samples with original moisture percentages of 14.5 to 16.1 maintained germination within recognized federal tolerance on the second test date of May 5 to June 5, 1958, except one sub-sample with an original moisture of 14.7 per cent. In comparison, all of the air-dried Group A sub-samples of the same seed maintained germination within testing tolerance.

When Group B sub-samples with natural moisture were tested for the third time on June 15, 1958, only four of the twenty-one sub-samples maintained germination within tolerance. These four sub-samples maintaining viability within tolerance included all of the sub-samples with original moistures in the percentage range of 14.5 to 14.7, except one sub-sample with an original moisture percentage of 14.7 which declined to 55 per cent in germination. Four sub-samples in the next highest original moisture range of 14.9 to 15.0 maintained germinations within one to three per cent of testing tolerance. The germination percentages of the remaining twelve sub-samples declined very rapidly as the original seed moisture increased from 15.0 to 17.6 per cent. In comparison, all of the air dried Group A sub-samples of the same seed, ranging in original moisture percentages from 14.5 to 16.4 maintained germination within testing tolerance.

Conclusions. In view of the assumptions made, limits imposed and research findings presented in this study, together with the results of other research cited in literature reviewed, the following general conclusions are given:

1) Soybean seed with original moisture of 15 per cent and above would not appear to maintain sufficient viability to warrant certification.
2) Based on previous research, there would appear to be little problem in maintaining viability of bagged soybean seed in Tennessee with moisture content of 14 per cent or less at time of certification through the first planting season under ordinary storage and handling conditions.
3) Soybean seed with original moisture percentages ranging from 14.5 to 15.0 would appear to be of questionable or even undependable viability.
4) Soybean seed rejected for certification due to moisture in excess of 14.0 per cent during the winter months, if then dried to 10 per cent moisture immediately following analysis, might be reconsidered for certification since viability may be expected to be maintained through the first planting season.
5) In light of other conclusions and because of variations in the initial viability and physical condition of soybean seed of individual growers, it would seem appropriate for the Tennessee Seed Certification Committee to recommend enforcement of the present 14 per cent maximum moisture standard

allowable before prescribing certification for such soybean seed.

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