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Open Storage of Soybean Seed in Mississippi

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Summary

Soybean seed of 'Davis' cultivar was stored in a warehouse at ambient conditions at Mississippi State University from June 1986 to June 1987 to observe the changes in warehouse and seed temperatures as well as seed moisture and germination during the latter stages of "carryover" storage. Two lots, consisting of 160 bags each, were stacked four pallets high, each pallet consisting of 40 bags. The effects of changes in outdoor ambient temperature and relative humidity on seed quality were evaluated according to the placement of individual bags within each stack. Ambient outdoor, ambient warehouse, and seed temperatures were monitored and recorded hourly. Seed moisture content and standard germination were determined every 30 days.

Fluctuations in ambient warehouse temperatures closely followed ambient outside fluctuations but were lesser in magnitude. Differences between the seed temperature of bags located in the inner portion of the stacks and seed temperature of bags located on the outside of the stacks were minimal; thus they were averaged at each of the three locations -- top, middle, and bottom of stack. Average maximum seed temperatures were closer to average outside ambient temperatures than were average minimum seed temperatures. Regression equations were derived to estimate maximum and minimum seed temperatures based on ambient outside maximum and minimum air temperatures. A multiple regression equation was developed to predict monthly average seed temperature based on monthly average ambient outside air maximum and minimum temperatures.

Seed moisture content fluctuated with seasonal changes in relative humidity and temperature. Greater fluctuations of moisture were observed in seeds at the top of the stack than at either the middle or bottom. Moisture was lower in June, July, and August and higher during the rest of the year as a result of seeds' attaining a lower equilibrium moisture content at higher temperatures. Moisture content of seeds in the interior (inner) bags was generally lower than that of seeds in the outside bags. Germination declined drastically during this study phase that represents the last 12 months of a typical 19-month carryover period . Germination of seeds at the top of the stack was significantly higher than germination of seeds from either the middle or bottom of the stack. This was attributed to the lower moisture content of seeds on the top of the stack during the warmer months in spite of the high temperature in that portion of the stack during the summer.

Introduction

Warehouse storage of seed differs from bulk storage in that (a) seeds are cleaned and packaged in bags; and (b) the storage structure is an open building or warehouse rather than a closed bin. Ambient (open) warehouse storage differs from conditioned storage in that no attempt is made to control either temperature and/or relative humidity. The ambient temperature and relative humidity (RH) fluctuations in warehouse storage greatly determine the quality of seeds during the storage period.

Wein and Kueneman (1981) reported that the viability of some lines of Southeast Asian and North American soybean seeds stored under ambient conditions of 80.6 to 89.6 °F and 80% RH was reduced by almost 50% in 8 months. Baskin and Viera (1980) demonstrated the changes in germination of 22 soybean seed lots that were stored for up to 9 months in open storage in the southeastern region of the United States. They were successful in predicting the degree of seed deterioration using different time/temperature combinations of accelerated aging.

Bosco, Popinigis, Peske, and Silveira (1980) studied the suitability of ambient conditions in different regions of Brazil for storage of cowpea seed in open storage. They observed that 81 °F and 61.7% relative humidity and 75 °F and 81.2% RH were favorable conditions for open storage for a period up to 8 months. After 12 months, germination and vigor dropped rapidly. At 80 °F and 83.3% RH, germination and vigor were significantly lower after only 4 months in storage.

The objectives of this study were:

- to characterize seed and ambient temperature changes in an open storage warehouse;
- to determine the magnitude of fluctuation in seed moisture in open storage; and
- to evaluate the effects of moisture fluctuation on seed germination according to stack position.

Materials and Methods

Two lots of the 'Davis' cultivar harvested in mid-October were conditioned at the Mississippi Foundation Seed Stocks conditioning plant and placed in 50-pound 3-ply paper bags. The two seed lots, identifed as Lot 1 and Lot 2, were placed in an open storage warehouse under ambient air conditions, with the bags stacked four pallets high, each pallet containing 40 bags in five layers of eight bags each (Figure 1). The warehouse was a prefabricated metal building (50 ft x 100 ft) with r=10 fiberglass insulated walls and roof. Ample ventilation was provided by a draft created as air entered eight 10.75-ft2 windows located 1 foot above the floor and escaped through the ridge vent. Traffic was equivalent to that experienced in any commercial warehouse. Monitoring of temperatures and seed quality attributes was initiated in June 1986.

A Barber Colman Data Pro® Model CT72-00004-001 (1700 Rock St., Rockford, IL) datalogger was used to record temperatures. The datalogger recorded hourly temperatures sensed by iron-constant thermocouples with a precision of 0.7 °F. Thermocouples were placed inside outer bags located 1.00, 5.75, and 12.3 feet from the floor in each stack, and these locations were designated "bottom-out," "middle-out," and "top-out," respectively. At these same locations in each stack, thermocouples were also placed inside bags within the center of the stacks and designated as "bottom-in," "middle-in," and "top-in." Therefore, seed temperatures were recorded at three locations, top, middle, and bottom of the stacks, and two positions at each location, in and out (Figure 1). In addition, thermocouples were placed inside the warehouse 1.64 feet away from the stacks at 1.00, 5.75, and 12.30 feet from the floor to measure ambient warehouse temperatures. Ambient outside temperatures were monitored by a thermocouple located outside the warehouse and protected from direct sun light. Seed samples were removed monthly from bags at each position (in and out) at each location (bottom, middle, and top) for seed moisture and standard germination evaluation (Figure 2).

Seed moisture content was determined by drying four replications of approximately 15 grams (g) of seed each in a forced-air oven at 221 °F (105 °C) for 24 hours. Moisture content was calculated on a wet weight basis. Standard germination tests were conducted according to the Association of Official Seed Analysts (AOSA) Rules for Testing Seeds (1985), except that four replications of 50 seeds each were tested instead of 100 seeds. Rolled paper towels were used as the germination substratum, and the seeds were germinated at an alternating temperature of 68°/ 86 °F (20 °/30 °C).

Statistical analyses were conducted separately for each lot. The experimental design was a randomized complete block replicated through time and arranged as a three by two factor factorial: three locations (bottom, middle, and top) and two positions (in and out). Moisture content was also analyzed monthly, and whenever significance was indicated by the analysis of variance, means were separated by Student Newman Keul's range test (SNK). Linear regression analyses were conducted on maximum and minimum seed temperatures on the basis of maximum and minimum ambient outside temperatures. Multiple regression analysis was conducted on average seed temperature as a function of maximum and minimum ambient outside air temperature.

Results and Discussion

Temperature Fluctuation

Warehouse temperature. Ambient outside and ambient warehouse temperatures during the study period are presented in Figure 3. Differences between ambient outside maximum and minimum temperatures were generally greater than 18 °F, except for the months of November, December, and January. Differences between maximum and minimum ambient warehouse temperatures were smaller than maximum and minimum outside ambient temperatures, being less than 9 °F from October through March and between 9 °F and 18 °F for the other months. Slightly greater differences between maximum and minimum ambient warehouse temperatures were observed nearer the ceiling than the floor. Differences in maximum ambient warehouse temperatures were greater among locations than differences in minimum ambient warehouse temperatures (Figure 3).

Seed temperature. Differences of temperature between the "in" and "out" positions at each location were minimal. Thus, the two temperatures were averaged for each location (top, middle, and bottom) of the stacks. Average monthly maximum seed temperatures at different locations in the stacks compared to the average monthly maximum ambient outside temperatures are shown in Figure 4. Average maximum seed temperatures were generally lower than ambient outside average maximum temperatures. Because of their proximity to the roof, temperature of seeds at the top location followed more closely the ambient outside temperature fluctuations than did the temperature of seeds at the middle and bottom locations in the stacks. There was a wider range between average maximum seed temperatures among different locations in the summer months than in the remainder of the year. Regression analyses provided adequate prediction equations of maximum seed temperature by location, based on maximum ambient outside temperature (Figure 5).

Average monthly minimum ambient outside temperature and average monthly minimum seed temperatures for each location are shown in Figure 6. During the warmer months, seed temperatures at the middle and top locations in the stacks remained almost equal and were slightly higher than temperatures at the bottom location in each stack. During the period of October through March, average minimum seed temperature remained essentially the same for the three locations in each stack. Average minimum seed temperatures at all locations were always higher than average minimum ambient outside air temperatures. Seed temperature did not change as drastically as air temperature because of the good insulating properties of seed. In general, differences between average minimum seed temperatures and average minimum ambient outside temperatures were greater than differences between average maximum seed temperatures and average maximum ambient outside temperatures. Regression analyses provided an adequate prediction equation of minimum seed temperature by location, based on outside minimum temperatures (Figure 7).

Maximum and minimum seed temperatures were combined to obtain an average seed temperature for the three locations. The resulting curves are depicted in Figure 8. It is interesting to note that average seed temperatures were closer to the maximum ambient outside air temperature than to the minimum ambient outside air temperature. As overall ambient outside air temperatures declined during the fall, the seed released heat more slowly, with the average seed temperature being the same as maximum ambient outside temperature in December. This is explained by the fact that soybean seeds (and all seeds for that matter) have a higher specific heat than air. Although it requires more energy to change seed temperature, seeds release energy more slowly.

The maximum and minimum ambient outside air temperatures and average seed temperatures in the middle of the stack were subjected to multiple regression analysis. The following equation was found to fit the data best (Figure 9):

$$Y = 12.366 + 0.038286X_1 + 0.962167X_2$$

where Y is the predicted average seed temperature (°F), X1 is the maximum ambient outside air temperature (°F), and X_2 is the minimum ambient outside air temperature (°F). This equation can be used to predict seed temperature in an open warehouse based on average monthly maximum and minimum ambient outside air temperatures. This information can be used in connection with other models to predict viability of seed in storage. These include the logarithmic model developed by Roberts and co-workers [Roberts (1960); Roberts (1961); Roberts and Abdalla (1968); Ellis and Roberts (1980); Ellis and Roberts (1980a); Ellis, Osei-Bonsu, and Roberts (1982); and Ellis, Hong, and Roberts (1989)].

Daily temperature changes. Figure 10 illustrates the temperature distribution on July 15, 1986. Ambient outside temperature fluctuated between 79 °F and 95 °C. Fluctuation of ambient warehouse temperature followed the same pattern, but within a more narrow range of temperatures, 82 to 92 °F. Seed temperature fluctuations at the top of the stack ranged from 84 to 88 °F, a difference of only 4 °F, which is relatively small when compared with 10 to 16 °F for ambient warehouse and outside temperatures, respectively. Seed temperatures at the bottom location fluctuated less than temperatures of seeds in the middle and top locations. Differences of seed temperature among locations fluctuated only 5 °F.

Moisture content

Seed moisture content fluctuated from 9.6% to approximately 12.6% during this study (Figure 11). Analysis of variance over all months did not reveal significant differences in moisture content among locations, even though differences were found between positions (Table 1). When moisture content was analyzed monthly, significant differences among locations were found in August, November, and from March through June (Table 2). During April, May, June, and August the moisture content of seeds on the top was significantly lower than that of seeds at the bottom location (Table 2 and Figure 11). Moisture content in the outer position of the stacks was significantly higher from July through March, with the exception of September. From April to June, however, the moisture content of seeds in the inner position was slightly higher than moisture content of seeds in the outer position, although not significantly different (Table 3).

Standard Germination

Generally, soybeans are stored from October through April, the equivalent of 7-9 months. This period usually consists of a bulk seed storage phase and a packaged seed storage phase. It is important to note that this study was initiated about 7 months after harvest and thus, the effects observed are those resulting from "carrying over" soybean seeds for approximately 19 months under ambient conditions.

Table 1. Moisture conents and germination of two soybean seedlots averaged over the entire storage period by location and position in stacks in open storage.

	Location			Position	
	Top	**Middle**	**Bottom**	**In**	**Out**
Lot 1	--- % ---				
Moisture	10.5a[1]	10.6a	10.6a	10.4b	10.7a
Germination	60.9a	55.0b	53.3b	54.3b	58.5a
Lot 2					
Moisture	10.5a	10.6a	10.7a	10.5a	10.7a
Germination	43.7a	41.8a	43.5a	44.2a	41.7b

[1]Means in the same row within the same factor (location or position) not sharing a coommon letter differ significantly at the 5% level of probability as determined by SNK.

During this storage period, germination decreased from 82 and 75% to 29 and 20% for Lot 1 and Lot 2, respectively, as shown in Figure 12. Significant differences in germination averaged over the 12-month period among locations were only found in Lot 1 (Table 1). Significantly higher germination of seeds in the outer position was observed in Lot 1, while the opposite was observed in Lot 2. This was attributed to the lower initial quality of Lot 2. Overall higher germination of seeds at the top position is explained by the lower moisture content despite the higher temperature to which they were exposed during the period of May through September. As pointed out by Harrington (1972), seed moisture content has a more pronounced effect on viability than does temperature. Therefore, the results of these studies reveal that under the climatic conditions of Mississippi, characterized by high temperatures during the summer months and high relative humidities throughout the year, "carrying over" soybean seeds beyond one planting season lowers seed quality substantially below planting seed quality. Hence, environmentally controlled or conditioned storage facilities must be utilized in order to maintain high quality seeds.

Table 2. Table of significance of seed moisture content by location and position of bags in stacks in open storage[1]

Month in Storage	Location	Position
July	ns	**
August	*	*
September	ns	ns
October	ns	**
November	*	**
December	ns	**
January	ns	**
February	ns	**
March	**	**
April	*	ns
May	*	ns
June	*	ns

[1] Interaction of Location x Position was not significant.

[*] Denotes significance at the 5% level of probability as determined by the F test.

** Denotes significance at the 1% level of probability as determined by the F test.

Table 3. Monthly seed moisture content by location and position of bags in stacks in open storage.

Month in Storage	Location			Position	
	Top	Middle	Bottom	In	Out
	-- % --				
July	11.18a[1]	11.45a	11.48a	11.21b	11.53a
August	9.73c	10.61b	11.25a	10.44b	10.62a
September	9.68a	10.14a	10.21a	10.00a	10.00a
October	9.86a	10.30a	10.62a	10.06b	10.47a
November	10.67a	10.18b	10.17b	10.04b	10.64a
December	11.68a	11.09a	10.61a	10.72b	11.53a
January	11.23a	11.17a	10.62a	10.71b	11.31a
February	10.02a	11.00a	10.38a	10.64b	10.97a
March	11.19a	11.13a	10.40b	10.63b	11.19a
April	9.25c	9.62b	9.99a	9.63a	9.60a
May	9.57b	9.51b	10.13a	9.67a	9.67a
June	9.27b	9.42b	9.90a	9.61a	9.44a

[1]Means in the same row within the same factor (location or position) not sharing a common letter differ significantly at the 5% level of probability as determined by SNK.

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