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Heated Air Drying of Soybean Seed

R. K. Matthes, A. H. Boyd and G. B. Welch

Soybeans are normally harvested after the moisture content has decreased to about 12-13% or less. In Mississippi early maturing varieties are subjected to relatively high temperatures and high humidity levels during the maturing period. Also, this time (September 1 - October 10) is often a period of very unsettled weather because of effects of tropical storms originating in the Gulf of Mexico. When these storms occur at maturing time there may be a period of as much as 1 to 2 weeks of frequent rains, temperatures near 80°F and relative humidities (RH) of 80% or more. Under such conditions seeds deteriorate rapidly in the field. While this has been a continuing problem for early maturing varieties and some later maturing varieties at various locations in the soybean producing areas every year, the wet conditons experienced at harvest time over virtually all the soybean belt the past two years has greatly increased interest in soybean drying for seed and grain. This study was initiated to help determine the feasibility of early harvest and mechanical drying to circumvent the above mentioned weather problems. The deep bed or bin drying method was selected for investigation because the major portion of equipment in use on seed and grain farms in this

area consists of round grain bins with perforated floors and a plenum chamber underneath. Where these have been available reasonable results have been obtained for grain drying but seed quality has not been consistent. Green, et al. (3) reported in Missouri that late-harvested seeds have a lower germination percentage than those harvested earlier in the season.

From earlier studies and production experience we feel the following statements about soybean drying are valid. The germination of soybean seed will be lowered if the drying air temperature is greater than 110°F. The germination and grade of soybeans may be lowered if the relative humidity of the drying air is less than 35-40%. Often the temperature must be lower than 110°F to prevent lowering the RH too much. The germination of soybean seed in the upper layers of a bin dryer are lowered if excessive time is required to dry these seed. The longer time required for drying the soybeans in the upper region of a bin dryer is mainly caused by insufficient air flow due to insufficient fan power or excessive soybean depth in the bin.

The objective of this phase of our soybean drying study was to determine the ranges for several of these drying parameters in which the germination of soybean seed is not lowered during drying with heated air. To be

more specific, these objectives are: (1) to determine the maximum initial moisture content from which soybeans can be dried with acceptable seed quality, (2) to determine the maximum time allowable for drying soybeans in a deep bed, and (3) to determine the minimum air flow rate for drying soybeans in a deep bed without loss of germination in the upper layer.

Description of Dryer

A dryer (Figure 1) was constructed with eight bins each 48 inches deep with 1 square foot of cross-sectional area. The air source is a 3 h.p. variable speed backward curved centrifugal fan. A central plenum chamber is located between the plenum chambers of the eight bins. Adjustable slide gates are located at the entrance of each of the bin plenum chambers making it possible to control the air flow through each of the bins.

Prior to entering the central plenum the air is heated by strip heaters to the lowest desired temperature in the eight bins. Each bin has an individual thermostat and a strip heater for individual temperature control.

Sampling holes are located vertically at 12-inch intervals in one side of each bin to remove seed samples for moisture content and germination determinations during the drying tests. Rubber stoppers are used to close the holes. Thermocouples are installed in the center of the bins at 6, 18 and 30 inches from the bottom and the temperatures are recorded by a strip chart recorder.

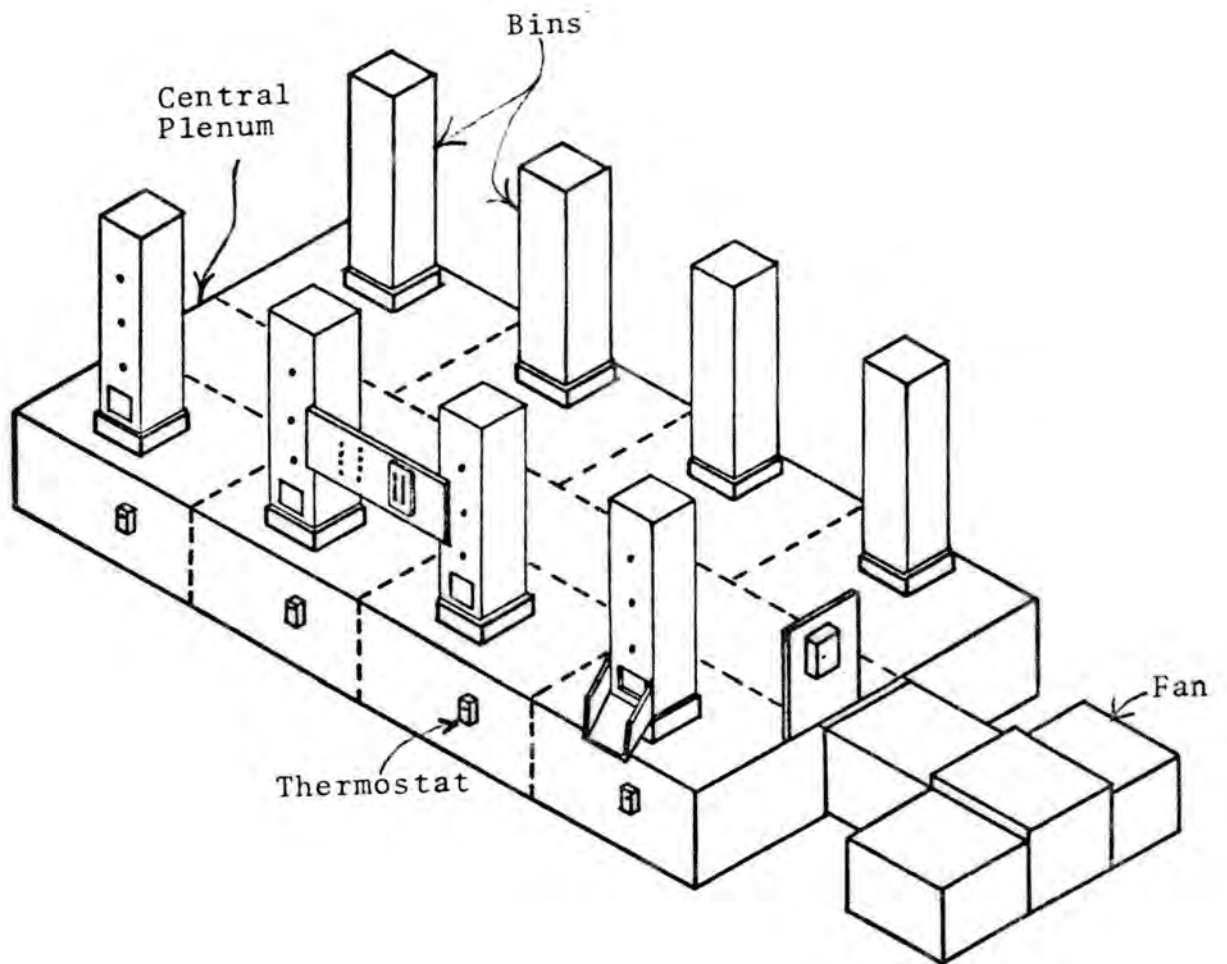


Figure 1. Experimental Seed Dryer

Drying Procedure

The Dare variety, an early maturing soybean, was harvested at 22% moisture and dried at a 48-inch depth, with relative humidities of 42% and 55%, and air flow rates of 1.5, 3, 6, 9, and 12 cfm/bu. The soybeans were brought immediately from the field, rough-cleaned with an M2B Clipper Seed Cleaner and loaded into the bins. The bins were filled to a uniform depth of 48 inches, and the air flow to each bin was adjusted to 3, 6, 9, and 12 cfm/bu for bins 1 through 4 respectively, and bins 8 through 5, respectively. A similar portable bin was attached to the central air plenum with a 2-inch hose and a 2-inch gate valve which was used to adjust the air flow in that bin to 1.5 cfm/bu. This bin was designated as bin number 9.

The thermostats were set on bins 1 through 4 and 9 to result in a high relative (55%) humidity for the drying air, and for bin 5 through 8 the thermostats were set to result in a lower relative humidity (40%) for the drying air.

The air flow rate of each bin was determined by a Velometer Air Flow Meter. The air flow rates were set at the beginning of the tests, checked periodically as drying progressed, and they remained relatively constant throughout.

Samples were taken during the tests at 8-hour intervals for the first 24 hours and at 12-hour intervals

thereafter until the top region of seed was dried (less than 12%). These samples were taken through holes in the side of the bins at the 6-inch, 18-inch, 30-inch, and 42-inch levels in the seedbed. The samples were placed in sealed glass jars and the moisture contents determined as soon as possible by the oven method. The remaining portions of the samples were placed in storage at 50°F and 45% RH for seed quality tests to be run at the completion of the drying.

Drying tests were also run on a lot of Lee 68 late maturing variety, but wet fields prevented harvest machinery entering the field until the seed had dried to 14% moisture. The above stated conditions of relative humidity and air flows from 3 to 12 cfm/bu all resulted in good drying and high germination. Two lots of Mack, an early maturing variety that has shown severe seed quality problems, were also dried from 18.5% moisture but the original germination was only 44%. It was interesting to note that although the best seeds did not even approach acceptable quality the germination of the dried seeds ranged from 44% down to 4.5% and the quality trend was the same as Dare.

Utilization of Temperature Profile

The rate at which a deep bed of seed is drying is indicated by the rate at which the drying front is moving through the seedbed in the direction of the drying air flow. The drying front is that region where the seed is actually

drying. Assuming the drying air to be moving up through the bin, the seed below the drying front are dry seed in equilibrium with the drying air and the seed above the drying front are moist seed equal to or somewhat higher in moisture than the initial moisture content of the seedbed. Knowing the location of the drying front is extremely helpful to the seedsman during drying. There is no simple, inexpensive method for obtaining a continuous record of seed moisture content at various levels in a seedbed.

Other investigations (1, 2) have pointed out an important phenomenon in deep-bed drying that, at the beginning of drying, the air temperature throughout the grain mass rapidly changes from the initial seed temperature to the so-called "psuedo-saturation" temperature. Once this temperature has been reached, the heating zone moves upward and, if drying is sufficiently prolonged, the entire batch approaches the drying temperature while the moisture content approaches the equilibrium moisture content. Thus, temperatures in a deep seedbed are indicative of the location of the drying front. Figure 2, illustrates how the temperature of a specific location in the seedbed indicates the position of the drying front relative to that location. Note that the temperature at the 6-inch level increases to 90°F in the first 8 hours of drying, while the moisture content decreases to 11%. The temperature at the 18-inch and 32-inch levels remains at 75°F ("psuedo-saturation" temperature) until drying commences at the 18-inch level in 16 hours and

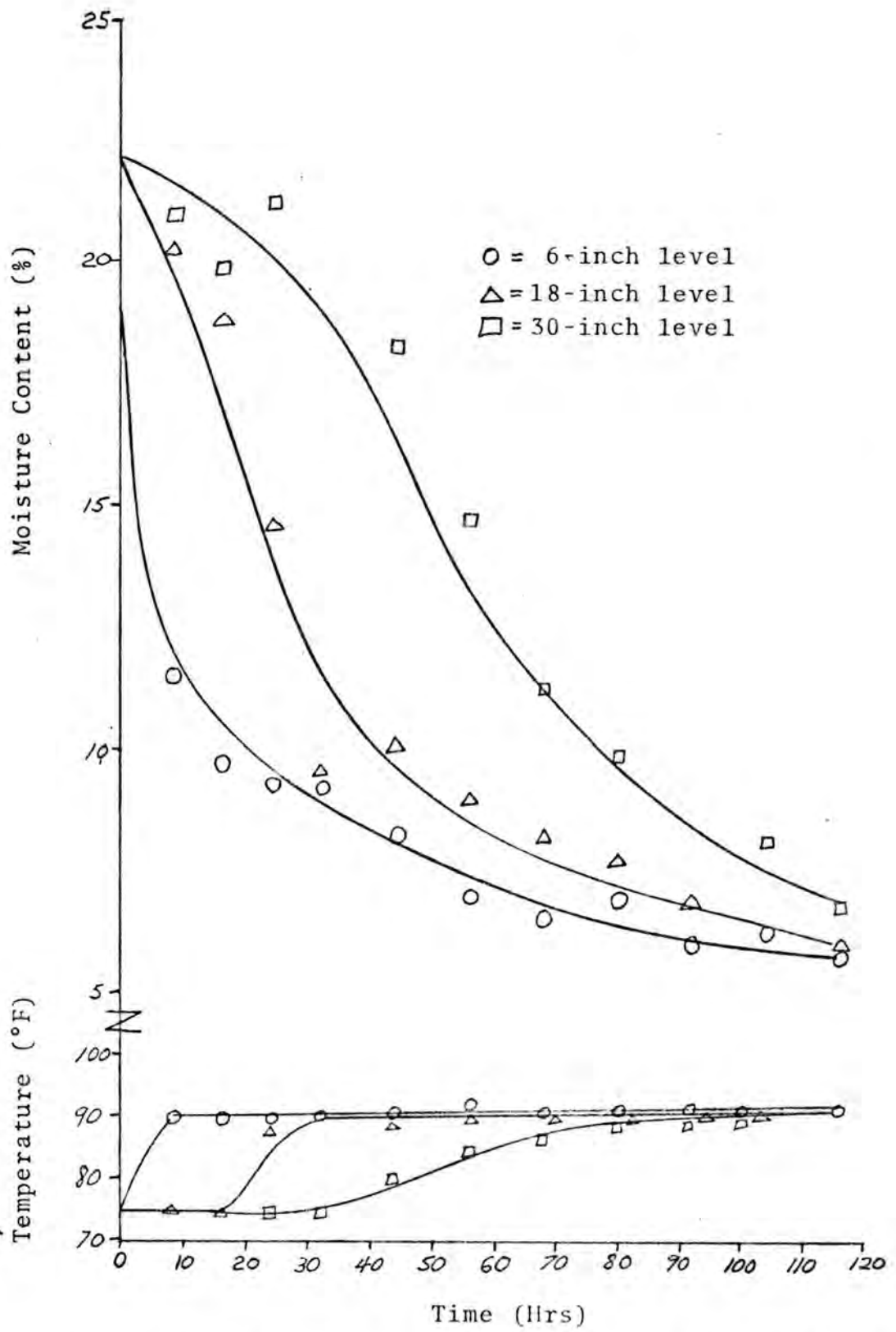


Figure 2. Moisture Content and Temperature Vs. Time Bin #7.

at the 32-inch level in 32 hours. "Psuedo-saturation" temperature is more adequately explained in earlier drying studies (1,2). Thus a recording of the temperature at several positions within the seed bed will assist the seedsman in following the rate of drying within the seedbed. When the temperature in the upper region of the seedbed approaches the drying air temperature drying of the seedbed is complete.

Analysis of Seed Quality

During the tests samples were taken periodically from four locations within the seedbed. Moisture content and germination determination were made on these samples. The germination tests were run on all the seed in the sample, i.e., no attempt was made to remove cracked or shriveled seed prior to the test. Graphs made of moisture content versus time and germination versus time (Figures 3 and 4) of the two bins with low air flow (3 cfm/bu) indicate that the germination throughout the bin was approximately the same during the early period of the drying; however, the germination of the seed at the 30 and 42-inch levels (Figure 3) drops below 60% after approximately 80 hours when drying has not taken place at these levels. Note that the germination of the seed at the 6-inch and 18-inch levels remain above 70% and that drying occurs at 16 and 68 hours, respectively. Seed above the drying front can be considered to be subjected to very poor storage

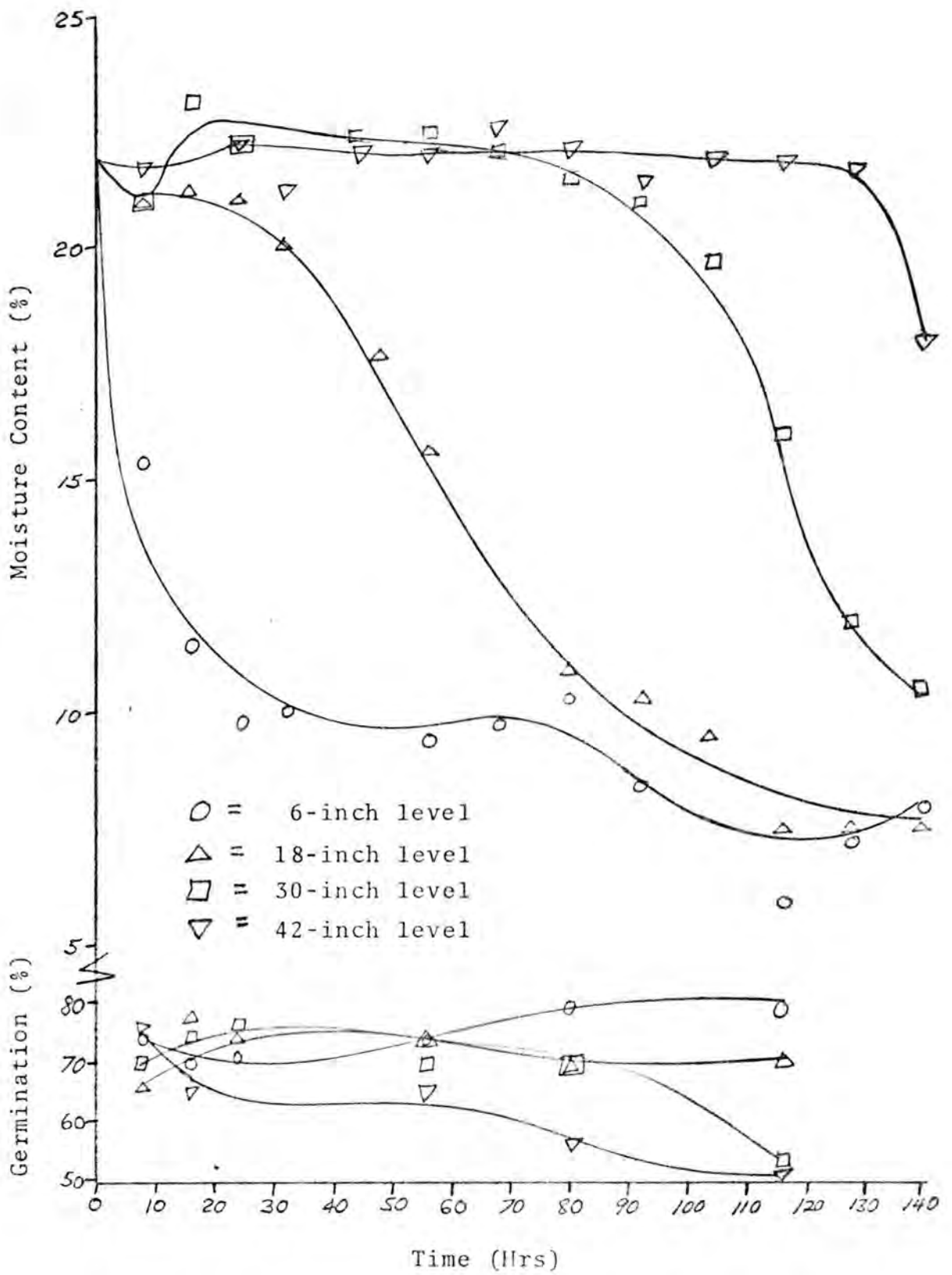


Figure 3. Moisture Content & Germination Vs. Time Bin #1.

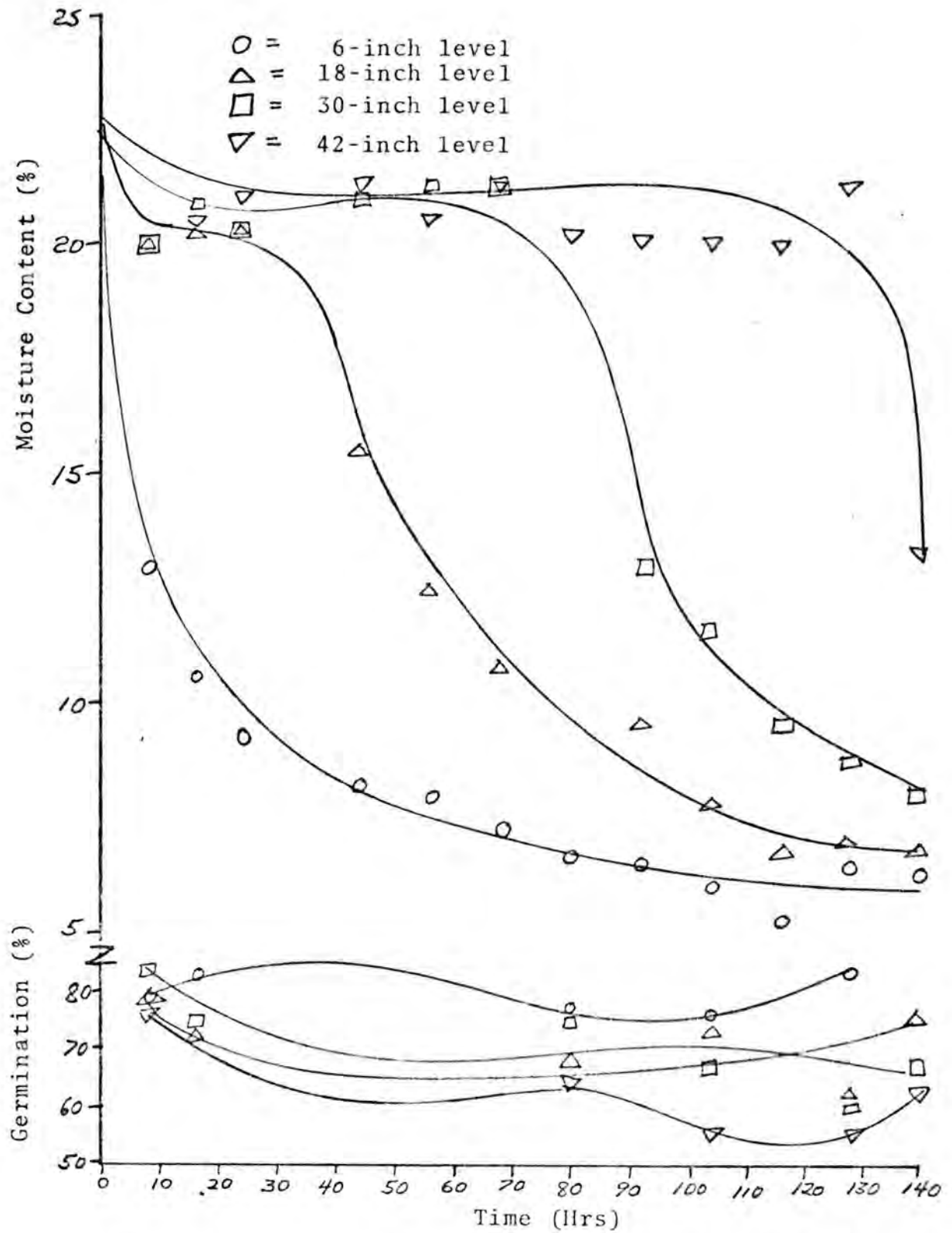


Figure 4. Moisture Content & Germination Vs. Time Bin #8.

conditions (75-80°F; 85% - 90% RH) while the seed are at 20% moisture content. One might expect that high moisture seed stored at such poor conditions for three days would experience a loss in germination, and this expectation is verified.

In this study, we are attempting to obtain a correlation between the seed quality (germination) and a measure of severity or quality of drying conditions. Major drying factors can be considered to be air flow, seed depth, drying air temperature and relative humidity but these are inter-related and separately do not show the entire drying picture. Referring to the previous discussion concerning drying times, it is noted that the time required for the seed at a particular level in the seedbed to be dried has a major effect on the seed quality. The drying time is really a composite effect of the drying conditions. We choose to investigate two times: (1) the time preceding the rapid decrease in moisture content or the time required for the drying front to reach the given level, and (2) the completion drying time or the time required for the seed to reach 12% moisture content. For example, in Figure 3 the drying front reaches the 30-inch level at 92 hours and drying is complete in 128 hours.

When the drying tests were completed a large sample of seed (5 lbs) was removed from each of the four levels in each of the bins. Each sample was run through a standard seed cleaning operation and then standard germination tests

were run. As expected, since cracked and shriveled seed were removed, these germination tests result in a higher germination percentage than those on the samples taken during the drying test where no cleaning was performed. The results of these tests are given in Table 1. For each of these points a beginning drying time and a completion drying time was determined from the moisture content curves. A computer correlation analysis program was done to determine which time was best correlated with seed germination. The correlation coefficient of seed germination with the beginning drying time is $-.84$ and that of the seed germination with the completion drying time is $-.88$; thus, the completion drying time is a somewhat better indication of the quality of drying conditions, and these are included in Table 1. Table 2 is an analysis of variance and regression coefficient of the completion drying time on the final germination of the seed samples. Note that R-Squared is 0.779 and the F value of 119.9 is significant at the 1% level of probability.

Taking 80% as a minimum acceptable germination percentage, note in Table 1 that only bins 5 & 6 with 42% RH and 12 and 9 cfm/bu, respectively, meet this minimum and that no bins with 55% RH drying air meet this minimum.

Conclusions

At this stage it is safe to conclude that high moisture soybean seed dried under similar conditions should have a

Table 2. Analysis of variance and regression coefficient for seed germination

DEPENDENT VARIABLE = SEED GERMINATION

INDEPENDENT VARIABLE = COMPLETION DRYING TIME

<u>Source</u>	<u>DF</u>	<u>Sum of Squares</u>	<u>Mean Square</u>	<u>F. Value</u>
Regression	1	.1674	.1673	119.90**
Deviations	34	.0475	.0014	
Total	35	.2148		

R-Squared = .779

Std Error of Estimate = .0374

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minimum air flow of 9-12 cfm/bu and that even higher cfm/bu are required if higher RH drying air is used.

As pointed out by Green, et al. (3) different varieties of soybean seed have different tolerances for high moisture, heat and other factors associated with drying; therefore, it would be a mistake to generalize the results of drying tests for one variety of soybeans to all varieties of soybeans. However, valid methods of analyzing drying data of one variety should be valid for other materials.

Keeping these points in mind, we can make the following conclusions concerning the drying of Dare soybean seed:

(1) It is feasible to dry high moisture seed (up to 22%) with heated air and obtain a finished product of acceptable quality.

(2) The relative humidity of the drying air can range from 40 to 50% RH.

(3) The air flow should not be less than 9-12 cfm/bu.

The following conclusions concerning the analysis of soybean drying tests can be made:

(1) A record of the temperature profile within a deep seedbed is a valid indication of the moisture content profile within the seedbed.

(2) There is a definite correlation between time required for drying seed and seed quality.

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