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Group IV Soybean Seed Quality

as Affected by Planting and Harvesting Date in the Mississippi Delta in 1996

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Introduction

Recent research has shown that maturity group IV soybean [*Glycine max* (L.) Merrill] cultivars may be profitable when planted early (Savoy et al. 1992; Backman et al. 1989). The principal advantage of these early-maturing cultivars is that plant growth and development occur during the period when rainfall is generally adequate. Seed production of Group IV soybean offers potential economic advantages in Mississippi. However, seed of these cultivars are not currently produced in Mississippi because they often mature under unfavorable conditions, such as high temperature, high humidity, and occasional rains. These conditions result in drastic reductions in the quality of seed produced due to the development of plant and seed pathogens (Damicone et a l. 1987; Hepperly et al. 1978; Kmetz et al. 1978; Kulik et al. 1981; Shortt et al. 1981). Consequently, most seed of group IV soybean cultivars are imported from other states where environmental conditions are more favorable for production of high quality seed.

Mayhew and Caviness (1994) suggested the potential for planting short-season, indeterminate cultivars in early April on well-drained, non-irrigated soils in the South. They reported that seeds harvested from group III and IV cultivars, which were planted in early April, experienced poor germination because of *Phomopsis longicoll a* infection. Within a specific region of adaptation, *Phomopsis* seed decay is greatest on early-maturing cultivars and decreases with increasingly later maturity (Shortt et al. 1981; Tekrony et al. 1984). Heatherly (1996) reported that planting group IV and V cultivars in April rather than May in the Midsouth can result in reduced germinability of seed from both non-irrigated and irrigated plantings. April plantings of group IV and V cultivars grown without irrigation always resulted in greater yields than when planted at later dates and grown without irrigation. He concluded that the success of the Early Soybean Production System concept is dependent on both early planting and use of indeterminate cultivars.

Green et al. (1965) indicated soybean plants that mature early during hot, dry periods yield lower-quality seeds than those that mature after temperatures drop. They further observed that low emergence percentages in the laboratory and field are associated with high occurrence of green cotyledons and wrinkled seed coats. Thomas and Raper (1978) observed only a slight effect of temperature on the number of days required for soybean flowers to open; however, subsequent growth and development of reproductive structures was highly temperature dependent. Combinations of warm days and warm nights produced the highest dry weights.

Boquet et al. (1983) studied the effects of planting date on yield and growth responses of five soybean cultivars at seven planting dates in Louisiana. They found that the poorest quality seed were harvested from the first (April 15) planting. Seed quality improved with delays in planting date and remained high until July 1 and 15 planting dates, at which time seed quality declined significantly.

Borba (1986) pointed out that planting soybean during the optimal planting period will increase yields but will not necessarily result in production of soybean seed with acceptable quality. He also reported that the post-maturation, pre-harvest environment has a much greater influence on quality of seed harvested than does either planting date or cultivar maturity date; consequently, soybean seed should be harvested as soon as possible after initial field maturity.

Adverse weather conditions during the post-maturation, pre-harvest period cause moderate to severe seed quality problems in soybean (Delouche 1980). Timely harvest of mature soybean seeds is extremely important in maintaining high seed quality. Harvest delays beyond optimum maturity increase field exposure and intensify seed deterioration. Green et al. (1965 and 1966) reported that when rain delayed soybean harvest after the seeds had initially declined to 13.5% moisture content, seed quality declined and subsequent reductions in germination and field emergence were seen. Tekrony et al. (1980) reported similar declines in vigor when seeds were harvested 30 days after harvest maturity, especially if hot, humid conditions prevailed.

Seed vigor and viability reach a peak at physiological maturity (Ching et al. 1972; Andrews 1966; and Trammell 1983). The rate of seed quality loss after physiological maturity depends on the degree of unfavorable environmental conditions surrounding the seed. Exposure to weathering is the major cause of seed quality loss following physiological maturity (Delouche 1980; Nangju 1980; Oropeza 1976; Sanchez 1984; Weerasena 1977; and Worrell 1982). Jongvanich (1981) found that germinability decreased with increasing length of the weathering period. Keigley and Mullen (1986) reported that high temperatures during the seed-filling period contributed directly to early deterioration of seeds and indirectly to *Phomopsis spp.* infection and deterioration that occurred after physiological maturity. Burdett (1977) reported that warm temperature at the time of maturity caused more rapid deterioration of early- or mid-season soybean cultivars; inherent genetic predispositions of the cultivars did not play a role in increasing their susceptibility to rapid deterioration.

During initial exposure to water, the seed coat functions to resist rapid uptake of water, but with repeated exposure, permeability of the seed coat increases sharply and permits rapid wetting and drying of the seed in the pod (Moore 1971). The stresses set up by rapid wetting and drying of the seed tissues initiates and accelerates deteriorative changes. Tekrony et al. (1980) found that soybean seed viability (germinability) was maintained at relatively high levels for 1 to 2 months following h arvest maturity, but seed vigor began to decline within a few days after the harvest maturity stage.

Heatherly (1993) indicated that irrigation of soybean from flowering through the seed-filling period significantly increased standard germination. Irrigation during the full reproductive period engendered both maximum seed yield and maximum germination of harvested seed.

Ferguson et al. (1990) found that soybean seed vigor, as measured by response to accelerated aging, declined to very low levels before there was any change in standard germination. Turnipseed (1993) reported that the conductivity of seed leachates, which is the most commonly used measure of seed permeability, increased as aging level increased for soybean. He found that seed vigor, as measured by accelerating aging response, was very high for seeds harvested at harvest maturity but decreased rapidly as weathering period and time in storage increased. The objectives of this study were (1) to identify the best planting time (early or late) for production of high-quality group IV soybean seed in Mississippi, and (2) to evaluate the effect of timing of harvest under these conditions.

Materials and Methods

Six cultivars of maturity group IV soybean (early maturing -- DP3456, HY4540, and A4715; and late maturing -- H4994, HBK49, and RA452) were planted at the Delta Branch Experiment Station in Stoneville, Mississippi, on a Tunica clay (clayey over loamy, montmorillonitic, nonacid, thermic vertic haplaquepts). Separate plantings were made on April 9, 1996, and May 14, 1996. Seeds planted in April were grown under two different conditions (non-irrigated and irrigated), whereas those planted in May were all irrigated. These represented three management systems: Early-Planted, Irrigated (EPI); Early-Planted, Non-irrigated (EPNI); and Late-Planted, Irrigated (LPI). Plots consisted of four rows, each 20 feet long with 30-inch row spacing. The experimental design was a randomized complete block with three blocks. Land preparation, insect control, and other cultural practices were in accord with recommendations for soybean production in this locality and were carried out by the MAFES Variety Testing program personnel (Askew et al. 1997).

Rainfall, temperature, relative humidity, and irrigation data were provided by the Delta Branch Experiment Station. Two inches of water were applied to the irrigated (furrow) plots on July 5, July 22, and August 21, 1996. Watermark sensors were placed at 6- and 12-inch depths in the soil to help determine the need for irrigation. Maturity was delayed because of rainfall during the latter part of the season.

Each plot was harvested twice. The first harvest was at physiological maturity, and the second was at 2 weeks after physiological maturity. The first harvest was made when seed moisture content was high (greater than 30% in some cases). Only one harvest (at physiological maturity) was made for the late-maturing cultivars planted on May 14, 1996, due to inclement weather. All plots were harvested by hand. The stems of the soybean plants were cut at the soil level, bagged, and transported to the seed laboratory for threshing and seed cleaning.

Seeds were air-dried by blowing ambient air through a bin. Seeds from the first harvest took 4 days to dry, whereas 1 day was sufficient for drying seeds from the second harvest. The bags collected from the field were hand-threshed using a stick. After threshing, large materials were removed, and a fractioning aspiration cleaner was used to clean the seeds. Mud, small stones, and remaining stems were removed by hand. Seed from each plot were then weighed.

Seeds were placed in storage under both ambient and controlled (cold room) conditions on October 15, 1996. The cold room was maintained at 10°C and 50% relative humidity. Seeds were sampled for laboratory evaluation prior to storage to determine germination and accelerated aging response. Seeds from each storage treatment were sampled again for laboratory evaluation on March 15, 1997, after 5 months in storage.

Seed moisture content was determined using the hot-air oven method. Immediately after each harvest, a sample of seeds from each replication was dried for 17 hours at 103°C. Moisture content was calculated on a wet-weight basis using the formula:

$$\mathbf{MC = [(WW - DW) / WW] \times 100}$$

where MC = moisture content (%), WW = wet weight of seed, and DW = dry weight of seed.

Germination tests were conducted according to the method specified in the Association of Official Seed Analysts' (1991) Rules for Testing Seed, except that 50 seeds were used for evaluating the germination, rather than the 100 seeds specified. A fungicide (thiram) was used to treat seeds after sampling from storage and prior to the germination test. The seeds were spread in moist germination towels, which were rolled and germinated at 20 °C for 16 hours and 30 °C for 8 hours. Counts were made 5 and 8 days after planting. The number of normal seedlings was recorded at each counting date.

Seed samples, treated with thiram, were aged using a Stults VWR Scientific accelerated aging chamber. Approximately 210 seeds from each replication and treatment were spread in single layers in screen baskets, which were kept inside plastic boxes containing 40 milliliters of water each. The boxes were hermetically sealed and placed in the chamber at 41 °C. After 72 hours, the seeds were removed from the chamber and germinated according to the procedures of the standard germination test described above. The temperature and time of aging were determined according to the suggested procedures for conducting vigor tests (AOSA's Seed Vigor Testing Handbook).

The data were subjected to analysis of variance using the general linear models (GLM) procedure of SAS (SAS Institute 1988). Means were separated using Fisher's protected least significant difference (LSD).

Results and Discussion

Seed Moisture Content

All two-way and three-way interactions of cultivar, harvest date, and management system were significant. Means for seed moisture content are presented in Table 1. Except for cultivars DP3456 and HY4540 under the EPI system, no significant differences in moisture content were observed between the two harvest dates for the early-maturing cultivars. Among the early-maturing cultivars, the seed moisture content for the first harvest of DP3 456 produced in the EPI system was significantly higher than that in the EPNI and LPI systems. The EPNI and LPI systems did not differ from each other for this cultivar. For cultivars HY4540 and A4715, seed moisture content at the first harvest under the EPI system was significantly lower than under the EPNI system, but it did not differ from the LPI system. At the second harvest date, seed moisture content appeared to reach equilibrium moisture content for all early-maturing cultivars. No significant differences were noted among systems or cultivars.

Among late-maturing cultivars, moisture content at the first harvest date was significantly higher than at the second harvest date for cultivars H4994 and HBK49 in the EPI and EPNI systems. The EPI system did not exhibit a significant difference in moisture content compared to the EPNI system. However, the LPI system exhibited significantly lower moisture content than the two early-planted systems for these two cultivars. At the second harvest, there were no significant differences in moisture content. This finding indicates that seeds of the late-maturing cultivars had reached equilibrium moisture content.

Cultivars DP3456, H4994, and HBK49 had high moisture content at the first harvest date due to the fact that these cultivars had more green seeds. RA452 matured earlier than the other late-maturing cultivars, which accounts for the lack of differences in moisture content for this cultivar.

Seed Yield

No interactions were observed for seed yield, but main effects of harvest date, production system, and cultivar were significant. Seed yields of each cultivar did not show any significant variation between the two harvest dates with the exception HBK49, which had higher seed yields at the second harvest date (Table 2). Moisture content of HBK49 was very high at the first harvest (Table 1). This cultivar was probably not at physiologic al maturity; therefore, the seeds were still accumulating dry matter at the time of first harvest.

There was not a significant difference between the EPI and EPNI systems for any cultivar or harvest date (Table

2). For early-maturing cultivars, the LPI system generally produced lower seed yields, regardless of harvest date. For late-maturing cultivars, there were no significant differences among the three systems.

Harvest date had little effect on seed yield. The EPI and EPNI systems produced the highest yields and did not differ from each other. The late-planted, irrigated system exhibited significantly lower yields for early-maturing cultivars. These results are similar to previous reports (May et al. 1989; Savoy et al. 1992; Heatherly 1996).

Pre-Storage Seed Quality

Standard Germination Test
All two-way interactions of cultivar, harvest date, and management system were significant for germination. There were significant differences in germination percentage between the two harvest dates for all cultivars in all three systems, with the exception of H4994 which did not exhibit any significant differences (Table 3). Germination percentage for the early-maturing cultivars in the two early-planted systems was much lower at the second harvest date than at the first harvest date. This reduction was the result of seed deterioration caused by unfavorable weather conditions in August, as well as associated fungal infection. Fungal infection was indicated by the large number of decayed seed observed during seedling evaluation of the second harvest of the early-maturing cultivars.

For the first harvest of the early-maturing cultivars, no significant differences in germination were observed among systems or cultivars. All cultivars exhibited greater than 80% germination.

At the second harvest, the LPI system exhibited significantly higher germination percentages than those of the EPI and EPNI systems for all three early-maturing cultivars. The only difference between the two early-planted systems at the second harvest was for cultivar HY4540 with the EPNI system, which showed higher germination than the EPI system.

At the first harvest, no significant differences in germination percentage between the EPI and EPNI systems were noted for the three late-maturing cultivars. The LPI system, however, exhibited a higher germination percentage than the two early-planted systems for cultivars H4994 and HBK49. Germination of the late cultivars did not differ in the LPI system at the first harvest date.

In general, seed from the LPI system had higher germination percentages than seed from the two early-planted systems. The late-maturing cultivars in the LPI system always germinated greater than 80% at the first harvest. These results corroborate the findings of Boquet et al. (1983) and Heatherly (1996).

Accelerated Aging Test
As with the standard germination test, all two-way interactions were significant. Except for the late-maturing cultivar H4994 in the EPNI system, seed vigor was significantly lower at the second harvest date (Table 4). The drastic reduction in seed vigor at the second harvest date for early-maturing cultivars resulted from unfavorable environmental conditions and fungal infection. Many decayed seeds, some of which were covered by mycelium, were observed at seedling evaluation.

The only differences among systems at the first harvest occurred with the early-maturing cultivar DP3456 and the late-maturing cultivar HBK49. In both cases, vigor was higher in the LPI system. Although DP3456 germinated greater than 80% in all systems at the first harvest according to the standard germination test, there was a reduction in seed vigor for the first harvest date of the EPI and EPNI systems (71.2% and 76.2%, respectively). All aged seed of HY4540, A4715, and RA452 germinated greater than 80 % at the first harvest.

At the second harvest, the highest seed vigor was observed for the LPI system, followed by the EPNI system and the EPI system for the early-maturing cultivars. Among late-maturing cultivars, only H4994 exhibited a significant difference between the EPI and EPNI systems. In this instance, higher seed vigor was obtained with the EPNI system. These findings support those of Delouche (1980), Tekrony et al. (1980), Ching et al. (1982), Andrews (1966), Oropeza (1976), and Trammell (1983).

Timely harvest (i.e. , at physiological maturity) contributed to improve seed quality of group IV soybean cultivars -- especially early-maturing cultivars -- regardless of the production system. However, the LPI system produced better quality seeds at the first harvest for all six cultivars. Seed moisture content at harvest in this system was 19.6% to 25%. Seed quality decreased drastically as harvest was delayed.

Post-Storage Seed Quality

The second seed quality evaluation was made after seeds had been stored for 5 months. There were no significant interactions with storage conditions (i.e., open storage and cold storage), and the data were combined for analysis of post-storage seed quality. There was, however, a significant three-way interaction among cultivar, management system, and harvest date for all variables.

Standard Germination
All early-maturing cultivars displayed a significant difference between the two harvest dates in all three systems (Table 5). For late-maturing cultivars, with the exception of RA452, there was no difference between the two harvest dates for the EPI or EPNI systems. RA452 exhibited higher germination at the first harvest in the EPI system.

At the first harvest, the seeds produced in all three systems were equal in germination percentage for the early-maturing cultivars. At the second harvest, seeds of early-maturing cultivars from the LPI system had a significantly higher germination percentage than seed produced in the two early-planted systems.

Among late-maturing cultivars, H4994 and HBK49 produced seed with significantly higher germination percentage in the LPI system at the first harvest date. At the second harvest, there were no significant differences between the EPI and EPNI systems for the late-maturing cultivars.

After storage, the early-maturing cultivars from the first harvest germinated greater than 80%, but they germinated below this critical value at the second harvest in all systems. For the late-maturing cultivars H4994 and HBK49, the seed produced in the two early-planted systems were associated with poor seed quality, even when harvested at the first date. For all cultivars, seeds from the LPI system at the first harvest date had consistently high germination (89.1% to 92.3%), compared with the early-planted systems (59.1% to 91.4%). In all systems, seeds from the second harvest had low germination (less than 80%) for all cultivars except RA452 in the EPNI system.

Accelerated Aging Test
Significant differences were observed for percent germination in the accelerated aging test between the two harvest dates in all systems for all cultivars (Table 6). Germination was always higher at the first harvest.

Seeds from the first harvest of DP3456 in the LPI system had the highest germination (81.7%). This germination rate was significantly higher than germination of seeds from the two early-planted systems. The EPI system produced seeds of DP3456 with significantly lower germination at the second harvest.

For HY4540, accelerated aging germination values for the EPNI and LPI systems were significantly higher than those of the EPI system at the first harvest date. The three systems were significantly different from each other at the second harvest date. The highest value was obtained for seeds from the LPI system, followed by the EPNI system.

No variation was noted among systems at the first harvest date for cultivar A4715. At the second harvest date, the LPI system produced seed with higher germination percentage than the two early-planted systems.

Among late-maturing cultivars, seeds of HBK49 had higher accelerated aging germination values. Seeds from the LPI system had the highest value at the first harvest. No significant differences were observed among the three systems for seeds of H4994 and RA452 at the first harvest date. At the second harvest date, the EPNI system produced seeds with higher values than the EPI system for cultivars H4994 and RA452.

The accelerated aging test results ranged from 62.1% to 86.7% germination for the first harvest. After aging, all cultivars germinated greater than 80% with the LPI system at the first harvest date. In the EPNI system, only

HY4540, A4715, H4994, and RA 452 had test values greater than 80% at the first harvest. Only RA452 showed a value greater than 80% for the EPI system at the first harvest. The LPI system was associated with better seed quality, compared to early-planted systems. The lower seed vigor results for the EPI and EPNI systems at the first harvest may have been due to high seed moisture content and environmental factors such as high temperature, relative humidity, and rainfall, as well as fungi encountered during the seed maturation period.

Summary

Higher seed yields were obtained from the early-planted, irrigated (EPI) and early-planted, nonirrigated (EPNI) systems, especially for early-maturing cultivars. However, seed quality was significantly reduced with these two systems, particularly if harvest was delayed beyond physiological maturity. The late-planted, irrigated (LPI) system with harvest shortly after physiological maturity resulted in the production of high-quality seeds of all cultivars. These seeds maintained a high level of quality until the following planting season. The EPI and EPNI systems accompanied by timely harvest (i.e., shortly after physiological maturity) produced good-quality seed of cultivars DP3456, HY4540, A4715, and RA452. Delayed harvest always resulted in lower-quality seed. The late-planted (mid-May), irrigated system with timely harvest (physiological maturity) appears to offer the best potential for seed production of group IV soybean cultivars in Mississippi. This implies that close monitoring of seed moisture content is needed. Also, harvesting should take place as soon as it is mechanically possible to thresh the seed and access to drying facilities is available. The early-planted systems were better suited for grain production than for seed production. There is a need for additional research on this subject and these studies should be repea ted.

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