Accepted for publication 10 November 2004. Published 18 April 2005.

Midsouthern USA Soybean Yield Affected by Maturity Group and Planting Date

Larry G. Heatherly, USDA-ARS, Crop Genetics and Production Research Unit, P. O. Box 343, Stoneville, MS 38776

Corresponding author: Larry G. Heatherly. larryheatherly@bellsouth.net

Heatherly, L. G. 2005. Midsouthern USA soybean yield affected by maturity group and planting date. Online. Crop Management doi:10.1094/CM-2005-0418-01-RS.

Abstract

Soybean (*Glycine max*) is planted from late March through June in the midsouthern USA due to time, production, and environmental constraints. These plantings may utilize cultivars from maturity groups (MG) IV through VII, and are grown in both nonirrigated and irrigated environments. In irrigated April and May plantings, MG IV cultivars produced greater yields with greater irrigation efficiency than did MG V, VI, and VII cultivars. In nonirrigated April plantings, MG IV and V cultivars produced yields similar to each other. In nonirrigated early-May plantings, cultivars from all MGs produced similar yields, but days to maturity increased with increasing MG. In nonirrigated late-May plantings, MG V through VII cultivars had greater yields, whereas MG VI and VII cultivars yielded the most in nonirrigated plantings made after 31 May. This study shows that planting cultivars that are later than necessary for maximum yield results in increased days to maturity and a concurrent greater risk of detrimental late-season effects from drought and pests regardless of the planting date.

Introduction

Soybean (*Glycine max*) is a major crop in the midsouthern USA, and is grown on approximately 8 million acres in the region (11). There are two major systems of production based on planting dates: (i) late March through late April plantings, which are categorized as early soybean production system plantings (ESPS) (5); and (ii) May and later plantings, which comprise the conventional soybean production system (CSPS) (5,6), and include doublecropped plantings behind winter wheat (*Triticum aestivum* L.) (14). Soybean planted in both systems is grown in both nonirrigated and irrigated environments. In 2003, the midsouthern states of Arkansas, Louisiana, and Mississippi had 36%, 28%, and 36% of the soybean crop planted before 1 May, between 31 April and 1 June, and after 31 May, respectively (11).

Knowledge of the yield potential of soybean cultivars when planted during a specified period is important for planning a soybean production system and for marketing the harvested crop. For irrigated production, knowledge of the amount of water required for cultivars planted during a particular period is necessary for irrigation planning, especially in situations with limited water. The objectives of this long-term (28 years) research were to determine yield trends from nonirrigated and irrigated soybean cultivars from MGs IV, V, VI, and VII when planted from late March through June, and to determine irrigation requirements and irrigation efficiency for cultivars of these MGs when planted during this period in the midsouthern USA.

General Methodology

A total of 172 field experiments (both irrigated and nonirrigated) were conducted on Sharkey clay soil (very-fine, smectitic, thermic Chromic Epiaquert) on or near the Delta Research and Extension Center at Stoneville, MS (33°26'N) from 1976 through 2003 to examine the effects of MG and planting date on soybean yield. Cultivars of MG IV, V, VI, and VII were used (Table 1). The MG designations are those provided by the originator of each cultivar. Cultivars were constantly deleted from and added to experiments as new releases became available. The utilization of specific MGs during the 28-

year period reflects the shift in production systems implemented during that time. Data from 2001 were not included because of severe seed rot that occurred before harvest of all cultivars.

Table 1. Soybean cultivars, their maturity group (MG) and years used in long-term yield evaluations at Stoneville, MS from 1976 to 2003.

Maturity group	Cultivar (Years used)	Maturity group	Cultivar (Years used)
MG IV	RA452 (1991-1995) Dixie 478 (1996-2000) H4994 (1997-1998) AP4880 (1998-2000) DK4762RR (1999) AG4702RR (2000-2003) SG498RR (2000-2002) HBK4891 (2002-2003) HBK4820RR (2003) DP3478 (1995-2001) DK4875 (1996) H4994RR (1998-2000) P9492RR (1999-2001) SG468RR (1999) AP4882 (2000-2003) P9482 (2000) DK4868RR (2002-2003) AG4701 (1996) AG4922 (1997) AG4601RR (1998) DP4750RR (1999) DP4690RR (1999-2002) DP4748S (2000-2003) AG4403RR (2001-2003) RT4809RR (2002-2003)	MG V	Bedford (1979-1983) AG5980 (1986-1990) H5164 (1989-1990) AG5979 (1991-1996) NKS5960 (1993-1994) HY574 (1996-1998) DP5806RR (1998) DP5644RR (1999) DPL345 (1981-1983) P9592 (1989-1996) AG5403 (1990) P9501 (1992-1995) P9511 (1998-1999) H5545 (1997) P9594 (1999-2003) AG5701RR (2000-2003) DPL105 (1984-1991) DPL415 (1989-1992) Hutcheson (1991-2002) DP3589 (1993-1996) DP3588 (1994-1998) DK5961RR (1997-1999) DP5354 (1999-2000)
MG VI	Tracy (1975-1980) Sharkey (1988-1994) Young (1989-1992) H6686 (1991-1992) Tracy M (1981-1989) Leflore (1986-1990) P9691 (1989) Centennial (1979-1992) AG6785 (1988-1992) P9641 (1990-1992)	MG VII	Bragg (1976-1980) Braxton (1981-1986)

All experiments were conducted in a randomized complete block design with four replicates. Plantings prior to 1980 were made in wide rows (40 inch), plantings from 1980 through 1998 were made in both wide and narrow (20 inch) rows, and plantings after 1998 were made in narrow rows. Row spacing in all experiments was appropriate for the cultivars within each experiment; that is, wide rows were appropriate for late-maturing cultivars used early in the period, and narrow rows were appropriate for early-maturing cultivars used later in the period (10). Seeding rates were within the range necessary for optimum production (7). Weeds were controlled with recommended herbicides applied pre- and/or post-emergence, plus cultivation in wide-row plantings. Insect pests were controlled when necessary with recommended insecticides.

Irrigation started each year at or near beginning bloom (R1) (4) and was continued until the full seed stage (R6) (4). This schedule is appropriate for achieving maximum yield from irrigated soybean (8). Irrigation water was applied in furrows through gated pipe whenever soil water potential at the 12-inch depth, as measured by tensiometers, decreased to about -50 centibars. Total irrigation water applied was measured and recorded for each irrigated planting. Irrigation efficiency was calculated as (irrigated yield - nonirrigated yield)/amount of applied irrigation water. Days to maturity (DTM) of soybean in irrigated plantings was calculated as the difference between planting date and maturity (R8) (4). All yields were calculated from harvested seed adjusted to 13% seed moisture content.

For data analyses, experiments were grouped into five planting dates: (i) A, before 16 April; (ii) B, 6 April to 1 May; (iii) C, 1 to 16 May; (iv) D, 16 May to 1 June; and (v) E, after 31 May. Planting dates A and B reflect the ESPS and contain only MG IV and V cultivars, whereas planting dates C, D, and E reflect the CSPS and contain cultivars from all four MGs. This assignment of MGs to the planting dates and production systems is supported by previous research (3). Three separate data sets were created for each production system: 1, yield results from nonirrigated environments; 2, DTM and yield results from irrigated environments; and 3, yield increase from irrigation, irrigation water added, and irrigation water-use efficiency results from nonirrigated and irrigated environments that occurred in the same experiment. Data sets 1 and 3 utilize all available data for calculating long-term yields, and contain unequal numbers of observations for nonirrigated and irrigated data sets in each planting date and production system. Data set three contains equal numbers of nonirrigated and irrigated observations within each planting date and production system, and was created to make direct comparisons of yield increases from irrigation and water use parameters.

Data used in all analyses were derived from averaging across replicates in each year/planting date/cultivar combination. Cultivars were classified into four MGs as described above. Analysis of variance (SAS PROC MIXED, SAS Institute, Cary, NC; 12) was used to test for significance of MG and planting date effects and their interactions within ESPS (A and B) and CSPS (C, D, and E). In the analyses, planting date, MG and the MG × planting date interaction were treated as fixed effects of interest. Years and cultivars within MG were random components for error, and the residual error was the interaction of years and cultivars. Mean comparisons were based on LSD values at $P \leq 0.05$.

Days to Maturity (DTM) in Irrigated Environments

April (ESPS) plantings. Days to maturity for MG IV cultivars averaged 18 days less than DTM for MG V cultivars (Table 2). Days to maturity decreased by an average of 6 days when plantings were made in the 16 April to 1 May period compared to plantings made in the before-16 April period.

May and later (CSPS) plantings. The MG × planting date set interaction significantly affected DTM (Table 3). In May plantings, DTM significantly increased with increasing MG. In plantings made after 31 May, DTM of MG IV cultivars (98 days) was the least, while DTM of MG VII cultivars (133 days) was the greatest. Difference in DTM between MG V and MG VI cultivars was not significant.

Table 2. Days to maturity and seed yield by planting date and maturity group within early soybean production system (ESPS) plantings grown in both nonirrigated and irrigated environments at Stoneville, MS, 1976-2003.

Planting date	**Maturity group**		**Avg.**
	IV	**V**	
	Days to maturity[x]		
A: Before 16 April	140	160	150 a[y]
B: 16 April to 1 May	136	152	144 b
Avg.	138 b	156 a	--
	Irrigated yield (bu/acre)		
A: Before 16 April	61.5	56.6	59.1 a
B: 16 April to 1 May	59.9	53.7	56.8 a
Avg.	60.7 a	55.2 b	--
	Nonirrigated yield (bu/acre)		
A: Before 16 April	40.6	37.9	39.3 a
B: 16 April to 1 May	34.6	33.7	34.2 b
Avg.	37.6 a	35.8 a	--

[x] Days from planting to full maturity (4) in irrigated environments.

[y] Average values within a row or column of a variable that are followed by the same letter are not significantly different at $P \leq 0.05$.

Table 3. Days to maturity and seed yield by planting date and maturity group within conventional soybean production system (CSPS) plantings grown in both nonirrigated and irrigated environments at Stoneville, MS, 1976-2003.

Planting date	**Maturity group**			
	IV	**V**	**VI**	**VII**
	Days to maturity[x]			
C: 1 to 16 May	127 aD[y]	138 aC	152 aB	161 aA
D: 16 May to 1 June	120 bD	128 bC	136 bB	153 bA
E: After 31 May	98 cC	117 cB	120 cB	133 cA
	Irrigated yield (bu/acre)			
C: 1 to 16 May	54.0 aA	48.6 aB	49.2 aAB	50.5 aAB
D: 16 May to 1 June	46.7 bA	45.7 aA	43.7 bA	46.0 abA
E: After 31 May	36.5 cB	37.8 bB	45.1 abA	43.4 bAB
	Nonirrigated yield (bu/acre)			
C: 1 to 16 May	25.9 aA	28.0 aA	26.1 aA	25.0 aA
D: 16 May to 1 June	22.1 abB	26.4 aA	28.6 aA	28.2 aA
E: After 31 May	17.4 bB	20.4 bB	27.4 aA	25.4 aA

[x] Days from planting to full maturity (4) in irrigated environments.

[y] Values within a column of a variable that are followed by the same lowercase letter are not significantly different. Values within a row of a variable that are followed by the same uppercase letter are not significantly different at $P \leq 0.05$.

Irrigated Yield

April (ESPS) plantings. Average yield of MG IV cultivars (60.7 bu/acre) was greater than that of MG V cultivars (55.2 bu/acre) (Table 2). Average yields from the before-16 April plantings (59.1 bu/acre) and the 16 April to 1 May plantings (56.8 bu/acre) were not significantly different.

May and later (CSPS) plantings. The MG × planting date set interaction significantly affected yield. In the 1 to 16 May plantings, yield of MG IV cultivars averaged 54.0 bu/acre, which was greater than the average yield of MG V cultivars (48.6 bu/acre) (Table 3). Cultivars from MG VI and MG VII averaged 49.2 and 50.5 bu/acre, respectively. In the 16 May to 1 June plantings, average yields of cultivars from all MGs were not different from each other. Thus, planting cultivars of MG V and later provided no yield advantage in irrigated May plantings. In plantings made after 31 May, yield of MG VI cultivars (45.1 bu/acre) was greater than yield of MG IV and V cultivars. Average yield of MG VII cultivars was not different from average yields of cultivars of the other MGs. Thus, planting MG VII cultivars provided no yield advantage in June plantings.

Nonirrigated Yield

April (ESPS) plantings. Yield differences between MG IV and V cultivars were not significant (Table 2). Average yield from plantings made during the before-16 April period (39.3 bu/acre) was significantly greater than that from the 16 April to 1 May period (34.2 bu/acre).

May and later (CSPS) plantings. The MG × planting date set interaction significantly affected yield. In the 1 to 16 May plantings, there was no difference in average yield among cultivars across all MGs (Table 3). In the 16 May to 1 June plantings, yields from MG V, VI, and VII cultivars were not different (26.4 to 28.6 bu/acre), but all exceeded the yield of MG IV cultivars (22.1 bu/acre). In the after-31 May plantings, average yields from MG VI and VII cultivars were greater than average yields from MG IV and MG V cultivars. In these nonirrigated CSPS environments, planting MG V and later cultivars provided no yield advantage in 1 to 16 May plantings compared to planting MG IV cultivars. Likewise, planting MG VI and later cultivars provided no further yield advantage in 16 May to 1 June plantings, and planting MG VII cultivars provided no further yield advantage in the after-31 May plantings compared to planting earlier MG cultivars. Average yields of MG IV and MG V cultivars declined significantly when planting occurred after 31 May. Average yields of MG VI and VII cultivars were not affected by planting date after 31 April.

Yield Increase from Irrigation and Irrigation Efficiency

April (ESPS) plantings. There were no differences in average yield increases across both MGs and both planting date sets (Table 4). Less irrigation water was applied to MG IV (7.5 inches) than to MG V (10.9 inches) cultivars in the before-16 April plantings, whereas the amounts of irrigation water applied to cultivars of both MGs in the 16 April to 1 May plantings were not different. Irrigation efficiency was greater for MG IV cultivars than for MG V cultivars in both April planting date sets. Irrigation efficiency of MG IV or MG V cultivars was not affected when planting occurred before 1 May.

May and later (CSPS) plantings. The MG × planting date interaction was significant for all variables. Yield increases from irrigating MG IV and V cultivars were greater in the May plantings than in the plantings made after 31 May (Table 5). Yield increases from irrigating MG VI cultivars were not different across planting dates, whereas irrigating MG VII cultivars produced greater yield increases in the 1 to 16 May planting dates. In the 1 to 16 May planting dates, yield increases from irrigating MG IV and VII cultivars were not different from each other, and both were greater than increases from irrigating MG V and VI cultivars. In the 16 May to 1 June planting dates, the trend indicated greater yield increases from irrigating MG IV and V cultivars. No significant differences in yield increases from irrigation between MGs were found when planting occurred after 31 May.

Table 4. Yield increase from irrigation, amount of irrigation water applied, and irrigation efficiency by planting date and maturity group in early soybean production system (ESPS) plantings at Stoneville, MS, 1976-2003.

Planting date	Maturity group IV	Maturity group V	Avg.
	Yield increase from irrigation (bu/acre)		
A: Before 16 April	19.8	17.2	18.5 a[x]
B: 16 April to 1 May	23.6	18.6	21.1 a
Avg.	21.7 a	17.9 a	
	Irrigation water (inches/acre)		
A: Before 16 April	7.5 b[y]	10.9 a	
B: 16 April to 1 May	11.0 a	11.5 a	
	Irrigation efficiency[z] (bu/acre/inch)		
A: Before 16 April	2.35	1.35	1.85 a
B: 16 April to 1 May	2.23	1.65	1.94 a
Avg.	2.29 a	1.50 a	

[x] Average values within a row or column of a variable that are followed by the same letter are not significantly different at $P \leq 0.05$.

[y] Irrigation water values followed by the same letter are not significantly different at $P \leq 0.05$.

[z] Bushels/acre yield increase from irrigation divided by inches of irrigation water. Values calculated from individual observations, not from table values.

Table 5. Yield increase from irrigation, amount of irrigation water applied, and irrigation efficiency by planting date and maturity group in conventional soybean production system (CSPS) plantings at Stoneville, MS, 1976-2003.

Planting date	Maturity group IV	Maturity group V	Maturity group VI	Maturity group VII
	Yield increase from irrigation (bu/acre)			
C: 1 to 16 May	27.0 aA[x]	20.0 aB	20.7 aB	25.5 aA
D: 16 May to 1 June	25.0 aA	21.2 aAB	16.3 aB	17.2 bB
E: After 31 May	13.9 bA	15.6 bA	17.4 aA	19.0 bA
	Irrigation water (inches/acre)			
C: 1 to 16 May	10.7 aA	12.1 aB	14.9 aC	16.8 aD
D: 16 May to 1 June	11.8 aA	12.4 aA	11.2 bA	10.6 bA
E: After 31 May	9.2 aA	9.0 bA	10.3 bA	10.4 bA
	Irrigation efficiency[y] (bu/acre/inch)			
C: 1 to 16 May	2.55 aA	1.63 aB	1.39 aB	1.61 aB
D: 16 May to 1 June	2.24 aA	1.76 aB	1.46 aB	1.63 aB
E: After 31 May	0.76 bC	1.45 aB	1.66 aAB	1.92 aA

[x] Values within a column of a variable that are followed by the same lowercase letter are not significantly different. Values within a row of a variable that are followed by the same uppercase letter are not significantly different at $P \leq 0.05$.

[y] Bushels/acre yield increase from irrigation divided by inches of irrigation water. Values calculated from individual observations, not from table values.

In the 1 to 16 May planting dates, the amount of applied irrigation water increased with increasing MG (10.7 inches for MG IVs to 16.8 inches for MG VIIs) (Table 5). At the later planting dates, amount of irrigation water did not differ among MGs. For MG IV cultivars, amount of irrigation water did not differ across planting dates. For MG V through VII cultivars, irrigation water applied generally declined with later planting.

In May plantings, irrigation efficiency was greatest when MG IV cultivars were used (Table 5). In plantings made after 31 May, irrigation efficiency was greatest when MG VI and MG VII cultivars were used. Irrigation efficiency decreased dramatically for MG IV cultivars planted after 31 May. For MG V through MG VII cultivars, irrigation efficiency did not change with planting date.

Discussion and Conclusions

The results of this assessment of long-term yield trends lead to several conclusions.

- MG IV cultivars in irrigated April plantings (sets A and B) produced superior yields and resulted in greater irrigation efficiency than MG V cultivars. In nonirrigated April plantings, yields from cultivars of MGs IV and V were similar. However, April plantings of MG V cultivars reached maturity 16 to 20 days later than MG IV cultivars. Thus, they are exposed to ambient conditions longer with no perceived benefit from the longer growing season. Therefore, MG IV cultivars should be selected for nonirrigated and irrigated ESPS plantings.
- Using MG IV cultivars in irrigated May plantings (sets C and D) resulted in greater yields and irrigation efficiencies compared to cultivars from MGs V, VI, and VII. Thus, MG IV cultivars should be selected for May plantings that are to be irrigated.
- In nonirrigated 1 to 16 May plantings (set C), planting cultivars from MGs IV through VII resulted in similar yield. However, the longer DTM of later-maturing cultivars indicates that early-maturing cultivars should be planted during this period.
- In nonirrigated plantings made during the 16 May to 1 June period (set D), MG IV cultivars had significantly lower yields when compared to cultivars from MGs V, VI, and VII, which produced similar yields. Since MG V cultivars were in the field for a shorter period than MG VI and VII cultivars, their use resulted in the best combination of high yield and shortest DTM in nonirrigated late-May plantings.
- In plantings made after May (set E), cultivars from all MGs produced relatively low yields, even with irrigation. In both nonirrigated and irrigated plantings made after 31 May, MG VI cultivars provided the best combination of yield and DTM.

The overall recommendations from these results are:

- Yields and irrigation efficiencies of irrigated April and May plantings of MG IV cultivars are high relative to all other planting date and MG combinations. This supports the premise that early planting of early-maturing cultivars should be used to achieve maximum yield and production efficiency for soybean production in the midsouthern USA. These results suggest expanding this concept to include early May plantings of MG IV cultivars grown using irrigation.
- Planting cultivars that are later than necessary for maximum yield results in increased DTM and the risk of detrimental late-season effects caused by insect pests (1,13) and drought (2,9) regardless of

planting date. These increased risks may not be reflected in yield, but will certainly be reflected in the increased cost associated with their abatement.

Acknowledgments

The author appreciates the technical assistance provided by Sandra Mosley, the statistical assistance provided by Debbie Boykin, and supplemental funding provided by the Mississippi Soybean Promotion Board and the United Soybean Board.

Literature Cited

1. Baur, M. E., Boethel, D. J., Boyd, M. L., Bowers, G. R., Way, M. O., Heatherly, L. G., Raab, J., and Ashlock, L. 2000. Arthropod populations in early soybean production systems in the midsouth. Environ. Entomol. 29:312-328.
2. Boykin, D. L. 2002. Weather data summary for 1971-2000, Stoneville, MS Online. Agric. Res. Serv., Mid-South Area.
3. Bowers, G. R. 1995. An early soybean production system for drought avoidance. J. Prod. Agric. 8:112-119.
4. Fehr, W. R., and Caviness, C. E. 1977. Stages of soybean development. Spec. Rep. 80. Iowa Agric. Exp. Stn., Ames.
5. Heatherly, L. G. Early soybean production system (ESPS). 1998. Pages 103-118 in: Soybean Production in the Mid-south. L. G. Heatherly and H. F. Hodges, eds. CRC Press, Boca Raton, FL.
6. Heatherly, L. G. Soybean irrigation. 1998. Pages 119-142 in: Soybean Production in the Mid-south. L. G. Heatherly and H. F. Hodges, eds. CRC Press, Boca Raton, FL.
7. Heatherly, L. G., and Elmore, R. W. 2004. Managing inputs for peak production. Pages 451-536 in: Soybean: Improvement, Production, and Uses, 3rd ed. J. Specht and R. Boerma, eds. Agronomy Monograph 16. Amer. Soc. Agron. Madison, WI.
8. Heatherly, L. G., and Ray, J. D. 2004. Corn and soybean. In: Irrigation of agricultural crops. Agronomy Monograph, 2nd ed. R. Lascano and R. Sojka, eds. Amer. Soc. Agron. Madison, WI. (In press).
9. Heatherly, L. G., and Spurlock, S. R. 2002. Small differences in planting date affect soybean performance in drought years. Miss. Agric. & For. Expt. Sta. Res. Rep. 23. Mississippi State, MS.
10. Heatherly, L. G., Blaine, A., Hodges, H., and Wesley, R. A. 1998. Variety selection, planting date, row spacing, and seeding rate. Pages 41-52 in: Soybean Production in the Mid-south. L. G. Heatherly and H. F. Hodges, eds. CRC Press, Boca Raton, FL.
11. National Agricultural Statistics Service. 2003. U.S. and state level data. Online.
12. SAS. 1999. SAS onlinedoc®, Version 8 [CD-ROM computer file]. SAS Institute, Inc., Cary, NC.
13. Taylor, O. 2004. Soyfax: Midsouth. Online. Looking South Communications, Brandon, MS.
14. Wesley, R. A. 1998. Doublecropping wheat and soybean. Pages 143-156 in: Soybean Production in the Mid-south. L. G. Heatherly and H. F. Hodges, ed. CRC Press, Boca Raton, FL.