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Soybean seed yield and quality under an ultra-short-season production system

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ABSTRACT

Drought is a major yield-limiting factor for soybean [*Glycine max.*] in the southern U.S.A. The ultra-short-season production system (USSPS), which uses maturity group (MG) 00 through I cultivars planted in April in Arkansas, may minimize severe yield reduction by drought since this system allows growers to harvest soybeans before severe drought occurs. The objective of this study was to evaluate yield potential and seed quality of Northern MG 00 through I soybean cultivars in a mid-South environment. Average yields of MG 00, 0 and I were 2954, 3585, and 3782 kg ha^{-1}, respectively, under irrigated conditions. Average yield under dryland production was significantly lower than that under irrigated production. However, some cultivars yielded significantly higher than the Arkansas state average (1881 kg ha^{-1}). Infection by seedborne fungi was minimal for all cultivars. Average germination rates under irrigated and non-irrigated production were 71, 71, and 68% for MG 00, 0, and I, respectively. There were large genotypic variations for seed yield and germination rate, suggesting cultivar selection is important for MG00 through I cultivars to be successful under the USSPS. These results show the potential of USSPS to produce a profitable crop in 79 to 100 d in the mid-South under both irrigated and dryland conditions.

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MEET THE STUDENT-AUTHOR

I am from Bolivia. I recently completed my sophomore year at the University of Arkansas pursuing a B.S degree in environmental, soil and water science. I came such a long way thanks to a partnership between Bolivia and Arkansas that gave me the opportunity to come to this school. I have been awarded the Charles A. Stutte Memorial Scholarship and the Dale A. and Wilhelmina S. Hinkle Scholarship. I had never worked on a farm or seen a soybean plant before coming to the university and working with the soybean breeding group. I worked closely with Tetsuaki Ishibashi on his Ph.D. project, and after one year I was given the opportunity to start a small research project. I am an active member in the Crop, Soil and Environmental Sciences Club and in the International Bolivian Organization. Through the CSES club I have gained experience in research, gotten to know some of the faculty, and made good friends. My long-term goal is to make a change for the better in quality of life in Latin America, and for this I find the need to look into graduate school to enhance my ability to educate people in environmental areas. I thank Dr. Chen and Tetsuaki for the opportunity they have given me to research soybean, which is one of the main crops in Bolivia. I am fortunate to be in this department and positive that I made the right choice.

INTRODUCTION

Soybean is generally grown as a full-season crop or a second crop in double-cropping systems in the southern U.S. Farmers in the mid-South usually grow maturity group (MG) IV, V, and VI cultivars planted in May through early July. These full-season cultivars bloom, set pods, and initiate or complete pod-fill from mid-July to early September. Drought is common from mid-July to early September in the mid-South (Scott et al., 1998), thus, soybean yield is greatly reduced in the mid-South.

Recently, soybean farmers in the mid-South have begun to plant MG III or IV cultivars in April or early May. This system is called the early soybean production system (ESPS), and it attempts to avoid the severe effect of drought on yield by completing the drought-sensitive growth stages before the drought occurs (Heatherly, 1999). However, yield from the ESPS is often unstable since MG III and IV cultivars usually do not mature until mid-August to early September in Arkansas. Reduced seed quality was also reported because of hot and humid conditions in Arkansas during the reproductive stages (Mayhew and Caviness, 1994).

Soybean yield may be improved by better matching of crop development with periods having sufficient soil moisture. A crop that matures before mid to late July is required to routinely avoid drought in the mid-South. This may be achieved by April plantings of MG 00 through I cultivars. We call this system an ultra-short season production system (USSPS). This system was tested in Arkansas and Missouri in 2000 and 2001, and high yield potentials of MG 00 through I soybean cultivars were observed in a 75 to 95-d growing season under irrigated condition (Ishibashi et al., 2003). Since critical reproductive development occurs when rainfall is likely to be more available, the USSPS may be capable of producing high yield under non-irrigated conditions. No research has been conducted on seed quality traits such as germinability and fungal seed infections for MG 00 through I soybean cultivars under the USSPS. Therefore, the objectives of this study were to estimate yield potential of MG 00 through I soybeans under the USSPS in irrigated and non-irrigated conditions, and to determine the quality of seed harvested from the USSPS.

MATERIALS AND METHODS

Field experiments were conducted at Fayetteville, Ark. in 2002 and 2003. A total of 174 MG 00 through I soybean cultivars were planted on the 25 of April in both 2002 and 2003 under irrigated and non-irrigated conditions. Three replications of each cultivar were planted. The soils were classified as Johnsburg slit loam (finesilty, mixed, active, mesic Aguic Fragiudoll). Seeds were treated with Apron Maxx (Syngenta. Greensboro, NC) (fungicide): (R)-[(2,6-dimethylphenyl)-methoxyacetyl-amino-propinic acid methyl ester], and planted with a grain drill at a rate of 80 seeds per m^2. The seven-row plots were 6 m long with 0.2 m between rows. A sprinkler irrigation system was used to irrigate the plots once for MG 00 cultivars and twice for MG 0 and I cultivars with 50 mm of water each time. Fertilizer, herbicide, and insecticide were applied as needed and based on Arkansas soybean production recommendations.

Seed yields of 5 to 7 rows from each plot were harvested with a plot combine and adjusted to 13% moisture. Plant height was measured at harvest maturity (R8) from soil surface to the tip of the main stem. Maturity was calculated as number of days from emergence (Ve) to harvest maturity (R8). The best 14 soybean cultivars from each MG were selected and standard germination tests were conducted using two 50-seed samples from each plot. Seeds were evenly placed in rolled germination paper and incubated at 25°C for 7 d (AOSA, 1988). The number of germinated seeds was counted and converted into germination percentage.

An agar plate assay was used to evaluate *phomopsis* seed infection. Fifty randomly chosen seeds were surface disinfected by soaking in 0.5% NaOCl solution for five minutes and rinsed with sterile deionized water for 2 min. Five disinfected seeds were placed on a petri dish containing potato dextrose agar medium with streptomycin, Danitol (Valent USA Corporation, Germantown, Tenn.)(nematicide, miticide)[alpha-cyano-3phenoxylbenzyl 2,2,3,3 tetramethyl cyclopropanecarboxylate], and acidified to pH 4.8 with lactic acid. Seeds in petri dishes were incubated at 25°C under light for 9 d. Fungi were identified based on colony morphology. Number of seeds infected by *Phomopsis longicolla* (*Phomopsis* seed decay), *Alternaria* spp., *Cercospora kikuchii* (purple seed stain), and *Fusarium* spp. were counted.

All field experiments were conducted with a randomized complete block design with three replications. The statistical software JMP 5.0.1 (SAS institute) was used for all data analyses (Windows NT v5.1).

RESULTS AND DISCUSSION

Seed Yield and Agronomic Traits

On average, MG 00 soybeans yielded 2954 and 1674 kg ha^{-1} under irrigated and non-irrigated conditions, respectively (Table 1). The growing season for MG 00 was the shortest with 87 and 82 d from emergence in Arkansas for irrigated and non-irrigated conditions, respectively. Plants of MG 00 cultivars were shorter than MG 0 and I cultivars, having an average height of 52 cm. The University of Arkansas Cooperative Extension Service Soybean Research Verification Program (SRVP)(2001) has managed 166 full-season irrigated and 36 non-irrigated fields for maximum productivity from 1982 to 2001. The average yields for these fields were 3245 and 1881 kg ha^{-1} for irrigated and non-irrigated experiments, respectively. Although the average yield of MG 00 soybeans under the USSPS was lower than that of full-season soybeans from SRVP, some cultivars yielded significantly higher than full-season soybeans. The best MG 00 cultivar yielded 3765 kg ha^{-1} with a single irrigation, whereas the best cultivar under non-irrigated conditions yielded 2536 kg ha^{-1}.

Yield potential and plant height increased as days to maturity increased (Table 1). Thus, MG 0 and I cultivars showed greater yield potential than MG 00 cultivars. Yields were 3585 kg ha^{-1} in 92 days and 3782 kg ha^{-1} in 96 days for MG 0 and I, respectively, under irrigation (Table 1). These average yields were higher than averages of full-season soybeans reported in SRVP and were achieved with two irrigation applications. However, yields from non-irrigated plots were low. It should be pointed out that there were significant genotypic variations for yield and height for MG 00 through I cultivars. This indicates the importance of cultivar selection for successful production of MG 00 through I soybeans under the USSPS. Moreover, significant positive correlation ($r = 0.72$) was found between seed yield and plant height (data not shown), indicating that plant height could be used as a selection criterion for high yield.

Physiological maturity (R7) occurred 5 to 7 d before R8 (data not shown) on average. MG 00 cultivars reached R7 by mid-July and MG 0 and I cultivars reached R7 in late July. Thus, these cultivars were capable of completely avoiding August drought and MG 00 cultivars could even avoid a late July drought at this location. The potential of the USSPS to produce a profitable crop in three months has important implications as water supplies become more limited in the mid-South.

Seed Quality

In general, seed-infecting fungi were low for MG 00 through I cultivars (Table 2). On average, over 80 and 75% of seeds were considered to be clean (without fungal infections) for irrigated and non-irrigated conditions, respectively (Table 2). Alternaria seed infection was the most prominent among all seed diseases observed in this study. Since it is hot and humid during the summer months in the mid-South, there is a concern about seed germinability as well as seed infection. Sinclair (1982) recognized phomopsis seed decay as a major cause of low seed germination, especially in the southern U.S. In addition, 32% and 39% germination for MG III and MG IV soybeans, respectively, under non-irrigated conditions (Mayhew and Caviness, 1994) was observed. They concluded that poor germination was associated with infection by *P. longicolla*. On average, 79, 77, and 65% germination was observed from seeds of MG 00, 0, and I cultivars, respectively, under irrigated conditions (Table 3). Better germination of MG 00 through I cultivars may have been due to a much shorter exposure to hot and humid conditions than was the case for MG III or later MGs. Generally, germination was lower in non-irrigated plots except for MG I. There were large genotypic variations for seed germination rate, ranging from 30 to 96% (data not shown), indicating the importance of cultivar selection. Visual seed-quality ratings were above average for irrigated plots while many were below average for non-irrigated condition, (Table 3). Lower visual estimates of seed quality in non-irrigated plots were due to an abnormal shape of the seed.

The results of the seed-quality evaluations suggest that seeds harvested from the USSPS are relatively clean and healthy. This is a positive outcome for soybean farmers since the USSPS requires much higher seeding rates to achieve maximum yield potential than does ESPS or conventional full-season production systems. The soybean in USSPS requires less irrigation during the annual drought cycle. Soybean farmers could save seeds from previous production and use them for the next plantings. In conclusion soybeans from MG 00, 0, and 1 produce an acceptable yield and good quality seed in Arkansas. The same conditions apply to all mid-South regions including Missouri, Tennessee, Mississippi, Kentucky, and others with similar soil and climatic characteristics. This system and its results are currently being tested in Mississippi and Arkansas on large soybean operations.

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Table 1. Average and best cultivar seed yield, plant height, and maturity of maturity (MG) 00 through I soybeans under irrigated and dryland conditions in 2002 and 2003.

MG (Irrigation treatment)	Seed yield (kg ha)$^{-1}$		Plant height		Maturity
	Average	Best	Average	Best	Average
MG 00 (Irrigated)	2954 a[z]	3765	55 a	76	87
MG 00 (Non-irrigated)	1674 b	2536	49 b	66	82
MG 0 (Irrigated)	3585 a	4742	65 a	87	92
MG 0 (Non-irrigated)	1611 b	2165	47 b	62	87
MG I (Irrigated)	3782 a	4909	69 a	93	96
MG I (Non-irrigated)	1676 b	2398	54 b	66	90

[z] Means in a column for each MG class not followed by the same letter significantly different at 5% level of probability.

Table 2. Average percentages and ranges of fungal infections for maturity group (MG) 00, 0, and I soybeans under irrigated and non-irrigated conditions in 2002 and 2003.

MG classification	Phomopsis (%)		Cercospora (%)		Alternaria (%)		Pathogen free (%)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
				Irrigated				
MG 00	0.4	0.0 - 2.0	1.8	0.0 - 6.7	6.2	0.0 - 16.0	79	46 - 94
MG 0	0.7	0.0 - 3.3	2.0	0.0 - 5.3	4.1	0.0 - 12.0	82	46 - 95
MG I	0.2	0.0 - 1.3	2.9	0.0 - 11.3	4.0	0.0 - 16.0	83	51 - 95
				Non-irrigated				
MG 00	0.3	0.0 - 2.7	0.9	0.0 - 4.7	4.9	0.7 - 19.3	81	35 - 97
MG 0	0.2	0.0 - 7.0	0.9	0.0 - 4.7	5.1	0.0 - 30.0	76	39 - 97
MG I	0.4	0.0 - 7.0	1.1	0.0 - 4.0	6.5	0.0 - 22.0	70	37 - 94

Table 3. Average seed quality rating and seed germination rate under irrigated and non-irrigated conditions for maturity group (MG) 00 through I cultivars in 2002 and 2003.

MG and Year	Seed Quality[z]	Seed Germination	Seed Quality	Seed Germination
	irrigated		non-irrigated	
MG 00-2002	2.3	71	2.6	65
MG 00-2003	2.7	86	3.2	61
2-year average	2.5	79	2.9	63
MG 0-2002	2.2	73	2.9	55
MG 0-2003	2.6	80	3.3	72
2-year average	2.4	77	3.1	64
MG I-2002	2.9	67	3.1	62
MG I-2003	2.9	62	3.5	79
2-year average	2.9	65	3.3	71

[z]Seed quality was visually estimated and rated 1 = very good to 5 = very good