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Soybean Planting Date and Maturity Effects on *Heterodera glycines* and *Macrophomina phaseolina* in Southeastern Kansas[1]

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Abstract: *Heterodera glycines* reproduction and damage potential were evaluated for *H. glycines*-resistant and -susceptible soybean cultivars from maturity groups (MG) III, IV, and V on two planting dates in each of two years (1990–1991). Infection by *H. glycines* reduced yields of late-planted susceptible cultivars to a lesser degree than early planted cultivars in 1990 but not in 1991. The MG V susceptible cultivar yielded better than earlier-maturing susceptible cultivars even when yields of resistant cultivars were similar across maturity groups. Soybean yields were a function of nematode densities on roots in 1990, and nematode soil densities and root colonization by the charcoal rot fungus, *Macrophomina phaseolina*, in 1991. Harvest densities of *H. glycines* were lower for late-planted than for early-planted susceptible soybeans in 1990; however, nematode population increase was more rapid on roots of late-planted soybeans in 1991. Soybean maturity group did not have a significant effect on nematode populations in either year of the study, but colonization rates of *M. phaseolina* were lower for MG V cultivars than for earlier-maturing cultivars. Delayed soybean planting and cultivar maturity selection do not appear to be viable management options for *H. glycines* in southeastern Kansas.

Key words: charcoal rot, *Glycine max*, *Heterodera glycines*, *Macrophomina phaseolina*, management, nematode, planting date, soybean cyst nematode, soybean maturity group.

Delayed planting date and the use of early maturing cultivars are among the recommended cultural practices for management of the soybean cyst nematode, *Heterodera glycines* (13). Late planting of soybean is a practice commonly associated with soybean–wheat double-cropping and can result in conditions that are detrimental to nematode development (1,11). Although delayed soybean planting in Missouri resulted in significantly lower *H. glycines* egg densities at planting, greater densities were observed at harvest (7). In Georgia, *H. glycines* populations were not affected by late planting and yield suppression due to the nematode actually increased (5).

Early maturing cultivars have been used in conjunction with late planting for *H. glycines* management in North Carolina (4,10). Lower egg populations develop on early maturing cultivars, presumably due to a shorter growing season (4). In southeastern Kansas, maturity group (MG) IV and V cultivars are typically chosen for full-season soybean production and are planted in late May through early June. Early maturing MG III cultivars are frequently double-cropped with wheat and are planted in late June through early July; however, these cultivars tend to be more susceptible to yield reductions due to the charcoal rot fungus *Macrophomina phaseolina* (8). Therefore, any evaluation of cropping procedures for *H. glycines* management in Kansas must also consider the potential impact of charcoal rot. The objectives of this study were to evaluate delayed soybean planting and cultivar maturity selection as potential management options for *H. glycines* in southeast Kansas.

Materials and Methods

Field plots were established in 1990 and 1991 in two fields with silt loam soil (22% sand, 61% silt, 17% clay, 1990; 34% sand, 46% silt, 20% clay, 1991) near Columbus, Kansas, that were naturally infested with *H. glycines* race 3. Two soybean cultivars, one susceptible and the other resistant to *H. glycines*, from each of three maturity

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groups were planted on two dates in both years. Susceptible cultivars for each maturity group were 'Pella' (MG III), 'Douglas' (MG IV), and 'Bay' (MG V). Resistant cultivars included 'Cartter' (MG III), 'TN4-86' (MG IV, 1990 only), 'Delsoy 4710' (MG IV, 1991 only), and 'Forrest' (MG V). Cultivars within maturity groups were chosen based on similarities in performance and maturity date in field evaluations in Kansas in the absence of *H. glycines* (W. T. Schapaugh, pers. comm.). Soybeans were planted in four-row plots 6.1 m long, with 75-cm row spacing on 21 June and 12 July 1990, and 29 May and 26 June 1991. The experimental design was a split-split plot with planting dates as whole plots, maturity groups as subplots, and cultivars within maturity group as sub-subplots. Whole plots were replicated four times, and subplots were randomized within whole plots.

Plots were cultivated and treated with the herbicides metolachlor and metribuzin at recommended rates prior to planting and were hand weeded as necessary during the growing season. Soybeans were harvested on 24 October 1990 and 22 October 1991 from 4.5 m of each of the middle two plot rows. The relative seed yields of the susceptible cultivars (yield of susceptible/yield of resistant cultivar) were a measure of yield loss due to *H. glycines* for each planting date and maturity group.

Cyst and egg densities of *H. glycines* were determined at planting and harvest from a composite soil sample of four 5-cm-d cores collected to a depth of 15 cm from the two middle rows of each plot. Numbers of cysts and eggs of *H. glycines* and propagules of *M. phaseolina* per gram of dry root were determined from composite samples of four root systems collected from the two outside rows of each plot on 9 September 1990, and 26 June, 31 July, 29 August, and 26 September 1991. Soybean growth stage evaluations were made according to Fehr et al. (3) on each sampling date.

Cysts in the soil were extracted from 100-cm^3 subsamples by a combination of sieving (12) and centrifugal flotation (6). Cysts on roots were dislodged with pressurized water and collected on a 150-μm-pore sieve. Eggs and second-stage juveniles (J2) were extracted by grinding the cysts against a polypropylene tube with a motorized stainless steel bit with 1-mm grooves (5) and counted at ×40 magnification. The efficiency of this procedure as determined by repeated grinding and sieving of selected samples averaged 30–40%, and numbers of eggs and J2 were adjusted accordingly. Following the removal of cysts, roots were surface-sterilized in 0.8% NaOCl, air-dried, and ground in a Wiley mill (8). Colonies of *M. phaseolina* were quantified from 100-mg subsamples of milled roots plated on chloroneb–rose bengal agar.

The data were subjected to analysis of variance. Nematode and fungal population data were $\log_{10}(x + 1)$-transformed before analysis. Regression analysis was used to compare linear trends in nematode population growth and fungal colonization of roots with respect to soybean growth stage among soybean cultivars and planting dates. Correlation and multiple regression analyses were used to examine relationships between soybean yields and pathogen populations.

Results

Effect of maturity and planting date on soybean yield: Planting dates were delayed in 1990 due to excessive rainfall in late May through early June. Reduced rainfall (65% below average) for the remainder of the 1990 growing season resulted in reduced yields (compared with 1991) among the early-maturing cultivars (MG III and IV) for both planting dates and among all cultivars for the July planting date (Table 1). There was a significant ($P < 0.01$) cultivar × planting date interaction for soybean yield in 1990 but not in 1991. Yields of susceptible cultivars averaged 35% lower than resistant cultivar yields for the early planting date but only 23% lower for the late planting date in 1990. Susceptible cultivars yielded 38% less than resistant culti-

TABLE 1. Effect of planting date and soybean maturity on seed yields of *Heterodera glycines*-resistant (R) and -susceptible (S) cultivars in southeastern Kansas.

	Seed yield (kg/ha)					
	1990			1991		
Main effect	R	S	RY†	R	S	RY
Planting date‡						
Early	1,033	648	0.65 a	1,259	797	0.62 a
Late	736	581	0.77 a	1,550	965	0.62 a
Maturity group						
III	635	581	0.97 a	1,303	743	0.57 b
IV	783	324	0.40 b	1,411	776	0.55 b
V	1,235	938	0.78 a	1,495	1,114	0.75 a

† RY = relative yield (calculated as: yield of susceptible cultivar/resistant cultivar). Means within a main effect followed by the same letter are not significantly different according to Fisher's LSD values for each effect ($P \leq 0.05$). Cultivar × planting date interaction significant ($P < 0.01$) for seed yields in 1990. Cultivar × maturity group interaction significant ($P \leq 0.05$) for seed yields in both years.

‡ Early planting dates were 21 June 1990 and 29 May 1991; late planting dates were 12 July 1990 and 26 June 1991.

vars on average for both planting dates in 1991.

The cultivar × maturity group interaction was significant ($P \leq 0.05$) for soybean yield in both years of the study. In 1990, susceptible cultivars yielded 3%, 60%, and 22% less than resistant cultivars in MG III, IV, and V, respectively. In 1991, susceptible cultivars in MG III and IV yielded 43–45% less than resistant cultivars, while the susceptible cultivar from MG V yielded 25% less than the resistant cultivar.

Effect of soybean maturity and planting date on H. glycines and M. phaseolina: Delayed planting did not significantly reduce *H. glycines* egg densities at planting (Pi) in either year of the study. Numbers of eggs/100 cm^3 soil ± SD averaged across maturity groups and cultivars for early vs. late planting dates, respectively, were 10,050 ±

TABLE 2. Effect of planting date and soybean maturity on *Heterodera glycines* final populations (eggs and J2/100 cm^3 soil) and reproductive rates on resistant (R) and susceptible (S) cultivars in southeastern Kansas.

	Pf†		Pf/Pi†	
Main effect	R	S	R	S
		1990		
Planting date				
21 June	4,167 ax‡	14,500 ay	0.6 ax	1.8 ay
12 July	3,750 ax	6,167 by	0.6 ax	0.9 bx
Maturity group				
III	3,275 ax	11,925 ay	0.4 ax	1.5 ay
IV	3,550 ax	11,112 ay	0.7 ax	1.5 ay
V	5,050 ax	7,950 ax	0.6 ax	1.0 ax
		1991		
Planting date				
29 May	1,652 ax	14,452 ay	0.4 ax	7.7 ay
26 June	978 ax	15,479 ay	0.4 ax	10.0 ay
Maturity group				
III	1,070 ax	14,967 ay	0.6 ax	4.9 ay
IV	1,719 ax	16,922 ay	0.4 ax	8.6 ay
V	1,156 ax	13,007 ay	0.3 ax	13.0 ay

† Pi = initial population (eggs and J2) per 100 cm^3 soil; Pf = final population (eggs and J2) per 100 cm^3 soil.

‡ Means followed by the same letter within cultivar and main effect (a-b) and between cultivar (x-y) within year are not significantly different according to Fisher's LSD values for each effect ($P \leq 0.05$). Cultivar × planting date and cultivar × maturity group interactions significant ($P \leq 0.05$) for Pf in 1990.

6,315 vs. 8,090 ± 4,321 in 1990 and 4,858 ± 4,240 vs. 2,833 ± 2,590 in 1991. There were significant cultivar × planting date and cultivar × maturity group interactions ($P \leq 0.05$) for egg densities at harvest (Pf) in 1990 (Table 2). On susceptible cultivars, Pf were lower for the late planting date, while on resistant cultivars Pf were similar between planting dates. Pf were higher on susceptible than on resistant cultivars for MG III and IV, but not V. In 1991, significant effects for Pf were limited to resistant vs. susceptible cultivars.

Numbers of eggs per g root from 9 September 1990 followed trends similar to those discussed for Pf in the same year. In 1991, *H. glycines* densities increased on roots of both resistant and susceptible cultivars during the reproductive phase of soybean growth. Linear regression analysis of log-transformed egg counts relative to soybean growth stage indicated that population increase was more rapid for the late-planted soybeans (Fig. 1). Differences in slopes were significant ($P \leq 0.05$) for planting date, while differences in intercepts were significant for cultivar (resistant vs. susceptible).

There was a planting date × maturity group interaction ($P \leq 0.05$) for *M. phaseolina* populations in both years of the study. For the single sampling date in 1990, this was due to the advanced development of MG III cultivars from the early planting date. Fungal densities in the roots of early-planted MG III cultivars were higher than for any other treatment combination. In 1991, regression slopes for fungal colonization relative to soybean growth stage were high on MG III cultivars and low on

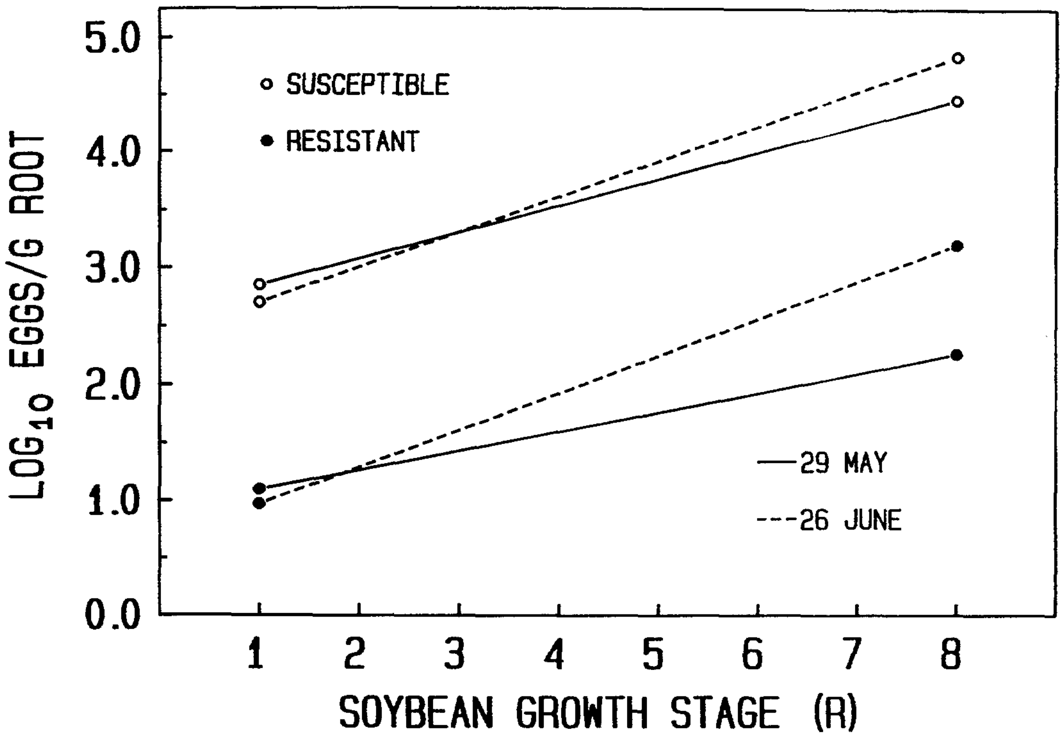

FIG. 1. Linear regressions of *Heterodera glycines* root densities with respect to soybean growth stage for resistant and susceptible cultivars on two planting dates in 1991. R = reproductive growth stage according to Fehr et al. (3). Regression equations for May and June planting dates, respectively, are: $Y = 0.93 + 0.17X$, $R^2 = 0.11$ and $Y = 0.65 + 0.32X$, $R^2 = 0.34$ for resistant cultivars; $Y = 2.63 + 0.23X$, $R^2 = 0.39$ and $Y = 2.40 + 0.31X$, $R^2 = 0.50$ for susceptible cultivars. Slopes and intercepts were significantly different ($P \leq 0.05$) for planting date and cultivar, respectively.

MG V cultivars for both planting dates (Fig. 2). Cultivars from MG IV had colonization rates (slopes) similar to MG III cultivars for the early planting date and MG V cultivars for the late planting date. No differences in colonization were observed between *H. glycines*-resistant and -susceptible cultivars.

Relationships between soybean yield and pathogen populations: Soybean yields for 1990 were negatively correlated with *H. glycines* egg densities from root samples collected 9 September ($r = -0.34$, $P = 0.02$). In 1991, soybean yields were a function of the additive effects of *H. glycines* egg densities from soil samples collected at planting and at harvest (Pi and Pf) and *M. phaseolina* root colonization on the last sampling date, which together accounted for 70% of the variation in seed weights.

Discussion

Delayed soybean planting has been suggested as a management procedure for reducing the damage potential of *H. glycines* (7,13). In Kansas, it appears that planting date has little effect on damage potential of the nematode unless soybean yield potential is severely limited as it was by drought for the late planting date in 1990. Under more favorable growing conditions, yield loss as measured in this study (the difference in yield between paired resistant and susceptible cultivars) was consistently 35–38% averaged across maturity groups. In contrast, yield loss was influenced by cultivar maturity, with the MG V cultivar Bay generally exhibiting less yield suppression than was observed for the shorter-season cultivars in MG III and IV.

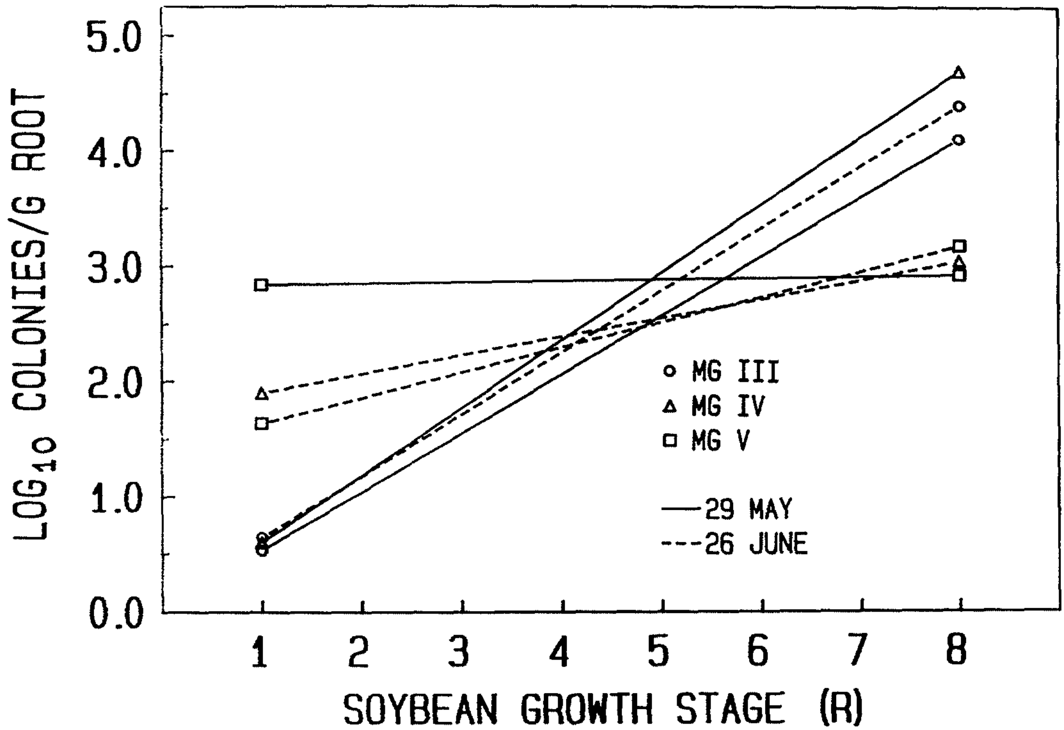

FIG. 2. Linear regressions of *Macrophomina phaseolina* root densities with respect to soybean growth stage for three maturity groups (MG) and two planting dates in 1991. R = reproductive growth stage according to Fehr et al. (3). Regression equations for May and June planting dates, respectively, are: MG III, $Y = 0.02 + 0.51X$, $R^2 = 0.55$ and $Y = 0.11 + 0.54X$, $R^2 = 0.71$; MG IV, $Y = 0.01 + 0.59X$, $R^2 = 0.75$ and $Y = 1.74 + 0.16X$, $R^2 = 0.15$; MG V, $Y = 2.83 + 0.01X$, $R^2 = 0.00$ and $Y = 1.42 + 0.22X$, $R^2 = 0.28$. Maturity group × planting date interaction significant for slope.

In southeast Kansas, long-season cultivars are exposed to fewer environmental stresses during their reproductive phase and appear to be more tolerant of *H. glycines* infection. The MG V cultivars selected for this study also differ from the earlier-maturing cultivars in determinacy. Cultivars in MG III–IV are indeterminate, while those in MG V are determinate. This trait is confounded with maturity in the present study, however, and further research is necessary to separate the two effects.

Our data confirm earlier observations by Pearson et al. (8) that much of the yield loss associated with charcoal rot in southeast Kansas can be avoided by planting MG V cultivars. The lower yield suppression observed for Bay in this study cannot be explained by reduced charcoal rot severity, however, since late-planted MG IV cultivars also had low *M. phaseolina* colonization rates but a high degree of yield suppression attributable to *H. glycines*. The *H. glycines*-resistant cultivars did not exhibit reduced levels of fungal colonization as was observed in a previous study (12); thus, yield differences between resistant and susceptible cultivars in this study are not likely to be confounded with charcoal rot effects.

Initial egg densities of *H. glycines* tended to be lower for the delayed planting dates in this study as was reported in Missouri (7). This did not translate into reduced yield loss, however. Harvest densities were also lower for late-planted soybeans in 1990, but this appeared to result from severely limited soybean growth due to drought stress. In 1991, *H. glycines* populations on soybean roots increased at a higher rate for late-planted soybeans, perhaps because root growth was static for early planted soybeans during much of the sampling period, while roots of late-planted soybeans were actively growing. Average daily soil temperatures during 1991 did not reach levels shown to be detrimental to *H. glycines* development (9) and since fewer days are required for life-cycle completion during summer months (2), conditions were presumably more favorable for rapid population increase on late-planted soybeans.

Maturity group had little effect on *H. glycines* densities. In particular, early maturing cultivars did not restrict nematode population increase as reported for North Carolina (4). Resistant cultivars reduced nematode densities an average of 48% during the growing season. This effect would likely be enhanced when resistant cultivars are double-cropped with wheat, as suggested by Koenning and Anand (7). Since MG III cultivars are particularly susceptible to charcoal rot damage, longer-season cultivars should be chosen when the planting date permits.

Based on the results of this study, neither planting date alone nor early-maturing susceptible cultivars are effective options for managing *H. glycines* in southeastern Kansas. Resistant cultivars and crop rotation continue to be the best management options available for soybean producers in this area.

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