Soybean maturity group and planting date effects on seed yield and population densities of *Heterodera glycines* [1]

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Summary – The effects of planting date and soybean maturity group on population densities of *Heterodera glycines*, the soybean cyst nematode (SCN), and soybean yield in the presence of this pathogen were determined in two series of factorial experiments. The first series of experiments evaluated May- versus June-planted soybean of two maturity groups (V and VII - early *vs* late maturity) with and without nematicide treatments at four North Carolina locations (environments) in 1986 and 1987. The second series of experiments concerned three planting dates (April, May and June) with four soybean maturity groups (IV-VII) at a total of six locations between 1989-1992. Delayed soybean planting resulted in a significant ($P \leq 0.05$) reduction in the initial population density *(Pi)* of SCN. The effects of planting date on final population densities *(Pf)* of SCN were usually significant, but not predictably so. Environmental differences associated with locations and planting date likely account for the significantly higher or lower *Pf*. Late-maturing soybean cultivars consistently resulted in greater SCN *Pf* at season's end than did early maturing cultivars ($P = 0.0001$). Soybean yields were increased by nematicides in early plantings ($P = 0.05$), but not in late plantings, probably a result of the attrition of SCN *Pi* in response to late planting. Mid-May planted soybean yields generally were the greatest of all planting dates.

Résumé – *Effets de la classe de précocité et de la date de semis du soja sur les rendements en grain et les taux de population d'*Heterodera glycines – Au cours de deux séries d'expérimentations factorielles ont été étudiés les effets de la classe de précocité et de la date du semis du soja sur les rendements en grains du soja et sur les taux de populations d'*Heterodera glycines*, le nématode à kyste du soja (SCN). La première série d'expérimentations a évalué les effets de semis en mai ou juin pour des cultivars de soja appartenant à deux classes de précocité (V et VI, hâtive et tardive), avec ou sans traitement nématicide, dans quatre localisations différentes (environnements différents) de la Caroline du Nord en 1986 et 1987. La deuxième série d'expérimentations a comparé les effets de trois dates de semis (avril, mai et juin) pour des cultivars de soja appartenant à quatre classes de précocité (IV à VII) dans six localisations différentes, de 1989 à 1992. Les semis tardifs ont provoqué une diminution significative ($P < 0.05$) des taux de population initiale *(Pi)* du SCN. La date de semis provoque un effet généralement significatif, mais impossible à prédire, sur les taux de population finale *(Pf)* du SCN. Les différences liées aux dates de semis et aux localisations des expérimentations sont probablement à l'origine des taux de *Pf* plus ou moins élevés. Le taux de *Pf* du SCN a été toujours plus élevé ($P < 0.0001$) avec les cultivars tardifs qu'avec les cultivars précoces. Les rendements du soja ont été plus élevés avec des semis précoces et avec des traitements nématicides ($P < 0.05$), mais pas avec des semis tardifs, probablement en relation avec la baisse des taux de *Pi* du SCN associée aux semis tardifs. Les semis effectués à la mi-mai correspondent généralement aux meilleurs rendements du soja.

Key-words : Cultural practices, ecology, *Glycine max, Heterodera glycines*, maturity group, planting date, population dynamics, soybean cyst nematode.

A significant portion of U.S. soybean (*Glycine max* [L.] Merr.) hectarage is infested with soybean cyst nematode (SCN) *Heterodera glycines* Ichinohe (Schmitt & Riggs, 1989). Damage caused by *H. glycines* varies from negligible to near crop failure, depending on its initial population density *(Pi)* and local environmental and edaphic factors (Francl & Dropkin, 1986; Schmitt & Riggs, 1989). Crop rotation, resistant cultivars, and nematicides have been employed to limit soybean yield losses caused by this pest (Schmitt & Nelson, 1987; Schmitt, 1991).

Rotation with nonhosts of *H. glycines*, such as corn (*Zea mays* L.) or grain sorghum *Sorghum bicolor* (L.) Moench), is an effective management strategy (Francl & Dropkin, 1986; Koening *et al.*, 1993). Frequently, nonhost culture for 2 or 3 years is required to reduce population densities of the parasite below levels damaging to soybean. This option is not acceptable to many growers for a variety of reasons, such as limitations placed on corn hectarage by government programs. Thus, economic or other factors make long-term rotations unfeasible for many growers. Currently available nematicides

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have not proven to be cost-effective for soybean (Schmitt, 1991).

Several studies have shown that cultural practices affect the population density of the soybean cyst nematode. Results of much research on SCN and cultural practices have been variable, indicating a need for regionalized research programs (Wrather *et al.,* 1992). Planting date had little effect on damage to soybean caused by *H. glycines* in Georgia (Hussey & Boerma, 1983). Subsequent research in Missouri indicated that the population density of *H. glycines* declined significantly from April to mid-June in the absence of a host, which may limit its damage potential on soybean (Koenning & Anand, 1991). Nevertheless, June-planted soybean tended to support greater numbers of SCN than May-planted soybean in several studies (Koenning & Anand, 1991; Koenning *et al.,* 1992). Research in Kansas showed that early planting had a significant effect on the final population density *(Pf)* of SCN one year, but not in the second year (Todd, 1993).

Soybean is grown as either a full- or short-season crop in much of the United States. Most soybean cultivars are adaptable to either system. Cropping systems can alter many aspects of crop production, affecting both host and pathogen. Delayed soybean planting may result in lower yields, but several advantages associated with late planting may offset yield losses. The ability to produce a winter wheat (*Triticum aestivum* L.) crop is one such advantage. Growers frequently produce both full- and short-season crops in order to spread planting and harvesting operations and thus optimize equipment usage. Soybean/wheat doublecropping may be practiced on 20-40 % of the southern U.S. soybean hectarage in any year.

Soybean maturity group (MG) can affect final population densities of *H. glycines* (Hill & Schmitt, 1989; Koenning *et al.,* 1993). A late maturing (MG VII) cultivar supported more soybean cyst nematodes than an early maturing one (MG V) in North Carolina. Significant effects of maturity group on SCN population were not observed when comparing indeterminate cultivars in maturity groups III-IV (Todd, 1993). Late maturing cultivars may extend the growing season into periods where environmental conditions are more favorable for *H. glycines* reproduction. Impact of maturity group may vary, depending on environment and whether determinate or indeterminate soybean cultivars are grown.

Our objective was to evaluate soybean planting date and maturity in terms of their influence on the reproduction and survival of *H. glycines* in a range of soil types and environments. Specific objectives were to : *i)* measure the attrition of SCN in the absence of a host from May to June; *ii)* evaluate planting date and soybean maturity effects on SCN final population density; and *iii)* determine the effects of planting date, nematicides, and maturity group on soybean yield in the presence of SCN.

Materials and methods

Two sets of factorial experiments were conducted to evaluate the effects of soybean planting date and maturity group on *H. glycines (Pf)* and soybean yield response from 1986-1992. All experiments were established in growers' fields naturally infested with SCN in the Tidewater and Coastal Plain regions of eastern North Carolina (Table 1). Soybean was planted at the rate of 26 seeds/meter of row. Row spacing varied by location from 0.91 to 1.01 m, depending on row width commonly used by the grower. Standard management practices for soybean production in North Carolina were used at each site. Seed yield of soybean was determined from the center two rows of each plot, and yields were adjusted to 13 % moisture. Both groups of experiments were arranged in randomized complete blocks with six replications.

The first set of experiments were conducted in four environments (three locations in 1986 : Craven, Currituck and Perquimans Counties; and one location in 1987 : Chowan County). A 2 × 2 × 3 factorial design with two planting dates (May and June), SNC susceptible soybean cultivars in two maturity groups (Deltapine 105 [MG V] and Ransom [MG VII]), and two nematicide treatments with an untreated control. Nematicide treatments, consisted of Aldicarb (Temik® 15G) applied at 1.68 kg a.i./ha in a 18 cm band and incorporated, and fenamiphos (Nemacur® 15G) applied at 2.35 kg a.i./ha in a 30 cm band and incorporated. Plots were four rows, 12.2 m long with 3 m alleys between replications.

The second group of factorial experiments was an unbalanced 3 × 3 factorial design with three planting dates (April, May, June) and three cultivars in maturity groups IV-VII. The soybean cultivar Pioneer 9442 (MG IV) was planted in April and May of each year, but a MG VI cultivar (Northrup King S69-96 in 1989, Young in 1990, and Deltapine 566 in 1991 and 1992) was planted instead of a MG IV cultivar in the June planting. This modification was used since it was assumed that the maturity group IV cultivar would not be suitable for late planting in North Carolina. Soybean cultivars Deltapine 105 (MG V) and Deltapine 417 (MG VII) were used in each planting every year. Six environments (Wayne County in 1989, Pasquotank and Robeson Counties in 1990, Wilson and Pasquotank Counties in 1991, and Hoke County in 1992) were used in this set of experiments. Plots for this set of experiments were 7.62 m long with four rows and 1.52 m alleys between replications. The MG IV soybean was harvested in late September to avoid yield losses due to shattering, whereas the rest of the plots were harvested in November.

Nematode population densities were evaluated from soil samples taken from the two center rows of each plot. All plots were sampled at the first planting date. Plots to

Table 1. *Location and year (environment), soil type and texture, mean preplant population density* (Pi) *of* Heterodera glycines *and standard deviation, planting dates, and inclusion of nematicide treatments used in field evaluation of soybean maturity groups.*

County/ Location	Year	Soil		Planting date			*Pi**	Nematicide treatment +/–
		type	% sand/silt/clay	1st planting	2nd planting	3rd planting		
Craven	1986	Onslow fine sandy loam	75/21/4	30 May	17 June	–	6,390 ± 6,860	+
Currituck	1986	Conetoe loamy sand	81/17/2	28 May	18 June	–	1,735 ± 1,195	+
Perquimans	1986	Timotley fine sandy loam	74/24/2	27 May	18 June	–	3,096 ± 1,491	+
Chowan	1987	Cainhoy fine sand	81/17/2	19 May	24 June	–	1,347 ± 1,243	+
Wayne	1989	Norfolk sandy loam	89/10/1	25 April	31 May	29 June	17,862 ± 6,447	–
Pasquotank (1)	1990	Bayboro loam	56/42/2	26 April	5 June	24 June	625 ± 1,012	–
Robeson	1990	Norfolk sandy loam	87/11/2	24 April	24 May	22 June	13,106 ± 6,614	–
Pasquotank (2)	1991	Nixonton fine sandy loam	48/44/8	18 April	22 May	18 June	7,167 ± 6,532	–
Wilson	1991	Coxville sand	90/ 9/1	17 April	15 May	20 June	18,663 ± 7,694	–
Hoke	1992	Norfolk sand	90/ 9/1	21 April	20 May	25 June	2,487 ± 3,712	–

* *Pi* : preplant population density of *Heterodera glycines* expressed as number of eggs/500 cm^3 of soil (mean ± standard deviation).

be planted at a later date were also sampled at planting. Soil samples taken for nematode analysis consisted of 15-20 cores, each 20 cm deep and 2.5 cm in diameter. Cores were composited, and a 500-cm^3 subsample was processed by elutriation (Byrd *et al.,* 1976), and centrifugation (Jenkins, 1964) to collect cysts and second-stage juveniles. Cysts were crushed in a Ten-Broeck homogenizer, and the eggs were extracted. Nematode data were transformed *(log_{10} [N + 1])* to standardize the variance for statistical analyses. The reduction in numbers of eggs over time was calculated as change in egg numbers per day = (eggs at time 2 - eggs at time 1) / (days between time 1 and time 2). Statistical analyses consisted of analyses of variance (ANOVA) and orthogonal contrasts for nematicide effects within planting dates. Statistical analyses of the change in nematode densities over time was accomplished using the General Linear Models procedure of SAS with preplant numbers of eggs + juveniles as a covariate (Anon., 1985).

Results

POPULATION DENSITIES OF *HETERODERA GLYCINES*

Population densities of *H. glycines* changed at a rate of from + 15 to – 30 eggs per 500 cm^3 soil per day between the first and second planting dates in 1986 and 1987 (Table 2). The rate of decline was not affected by environment for this set of experiments. Rates of change in subsequent experiments conducted from 1989-1992 tended to be greater than in the previous experiment varying from + 85 to – 167 eggs + J2s per day (Table 2). Environments for both series of experiments and the environment × interval (1st to 2nd planting *vs* 1st to 3rd planting) interaction for the years 1989-1992 differed significantly ($P = 0.01$) in the observed rates of decline. Preplant densities of eggs + juveniles *(Pi)* were used as a covariate in these analyses and had a highly significant ($P = 0.0001$) negative impact (higher rate of

Table 2. *Changes per day in population densities [least squares means (L.S.-Mean), standard errors (S.E.) and probabilities that mean is different from 0 (Probability > T)] of* Heterodera glycines *eggs + 2nd stage juvenile/500 cm³ soil as influenced by a delay in planting at ten environments from 1987-1992.*

County/ Location	1st to 2nd planting				1st to 3rd planting			
	L.S. △ eggs + J2/day			Time interval (days)	L.S. △ eggs + J2/day			Time interval (days)
	Mean	S.E.	P > T		Mean	S.E.	P > T	
Craven*	+ 15	10	0.1409	21	–	–	–	–
Currituck*	– 23	9	0.0171	21	–	–	–	–
Perquimans*	– 25	9	0.0104	22	–	–	–	–
Chowan*	– 31	9	0.0026	36	–	–	–	–
Wayne**	– 104	47	0.0350	36	1	47	0.9761	65
Pasquotank (1)**	– 167	41	0.0004	40	– 165	38	0.0002	64
Robeson**	+ 85	35	0.0228	30	85	35	0.0222	59
Pasquotank (2)**	– 105	33	0.0038	34	– 128	34	0.0007	61
Wilson**	– 52	39	0.1901	28	94	39	0.0225	64
Hoke**	– 152	36	0.0002	29	– 160	37	0.0002	64

* Data are based on means of 36 observations per environment. Analyses are of change/day with preplant density of eggs and second-stage juveniles as a covariate, and environments as fixed effects. Environments were not significantly different ($P = 0.05$).
** Data are means of 18 observations for each environment. Analyses are of change/day with environments as fixed effects and time intervals as random effects. Environment and the environment × interval effects were significant ($P < 0.01$), but the intervals did not differ.

decline with increasing *Pi*) on rates of attrition in both sets of experiments.

The influence of MG on final SCN population densities was consistent over environments and planting dates. Late maturing varieties resulted in greater *Pf* of *H. glycines* in all experiments (Figs 1 A-B; 2). First-order interactions of MG with other factors were not significant (Table 3). Planting date effects on *H. glycines Pf* were not significant in the first set of experiments (1986-1987), but had a significant ($P > 0.05$) impact in the second (1989-1992) series (Table 3). Late plantings tended to have higher numbers of SCN eggs than early plantings (Figs 1 A-B; 2), but the first order planting date by environment interaction was highly significant for both experimental series (Table 3). May-planted soybean had greater final SCN egg densities at Craven County in 1986 than June-planted soybean, whereas late planted soybean had much greater SCN *Pf* at Chowan County in 1987 than May-planted soybean (Fig. 1). Similar inconsistencies in planting date effects on *H. glycines* numbers occurred in the second experimental series. For example, there was a linear decrease in SCN *Pf* with delayed planting at Hoke County in 1992, but most other sites had highest SCN population densities with late planting (Fig. 3). The effects of nematicide treatments on final SCN numbers were not significantly different from the controls (data not included).

Soybean yield

The impact of planting date on soybean seed yield was significant ($P < 0.05$) in the series of experiments

Table 3. *Analyses of variance (P > F) of final egg population density* (Pf) *and soybean yield as influenced by environment, planting date, soybean maturity group (MG), and nematicide treatments at four North Carolina locations in 1986 and 1987.*

Factor (1)	P > F			
	Pf		Soybean seed yield	
	1986-1987 (2)	1989-1992 (3)	1986-1987	1989-1992
Environment (E)	0.0001	0.0001	0.0001	0.001
Planting Date (PD)	0.1716	0.0119	0.0103	0.001
Nematicide (N)	0.2308	-	0.0014	-
Maturity Group (MG)	0.0001	0.0001	0.1222	0.0759
EX PD	0.0001	0.0001	0.0002	0.0154
E X MG	0.2629	0.2691	0.0005	0.0001
PD X N	0.4016	-	0.0342	-
PD X MG	0.5600	0.1781	0.0054	0.0001
E X PD X MG	0.4665	0.4457	0.0479	0.3633

(1) Interactions that are not significant in either experiment are not included.
(2) Experiments in 1986-1987 were analyzed as a 4 × 2 × 3 × 2 factorial with four environments, two planting dates (May *vs* June), two maturity groups (MG V *vs* MG VII) and three nematicide treatments (control, fenamiphos or aldicarb).
(3) Experiments from 1989-1992 were analyzed as a 6 × 3 × 4 factorial with six environments, the three planting dates (April-June) and four maturity groups (MG IV - MG VII). A maturity group VI cultivar was substituted for the maturity group IV cultivar in the June planting.

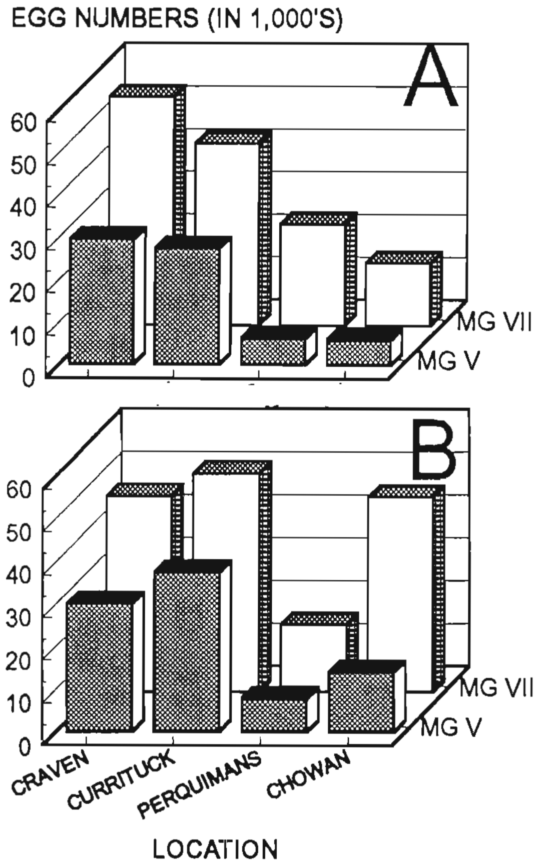

Fig. 1. *Final population densities of* Heterodera glycines *eggs/500 cm³ soil for two planting dates - May (A) and June (B) as influenced by location and soybean maturity group (MG V vs MG VII) in 1986 and 1987. Data are means of treated and untreated plots (18 replications). Nematicides had no effect (P < 0.10) on SCN* Pf, *but maturity groups MG were significantly different (P = 0.01) and the location by planting date (L × PD) interaction was significant (P > 0.01).*

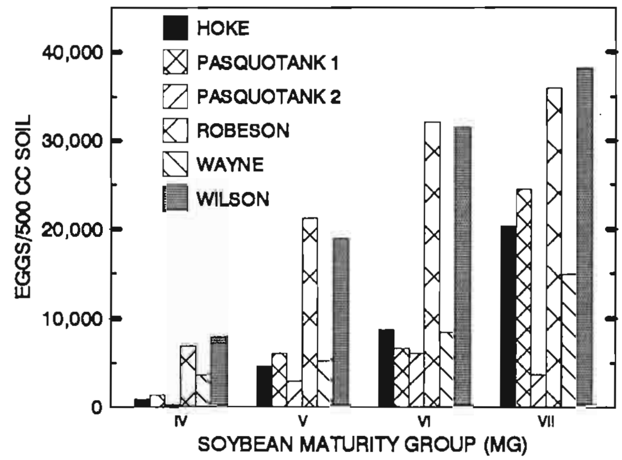

Fig. 2. *Soybean maturity group and location effects on* Heterodera glycines *final egg population densities/500 cm³ soil averaged over three planting dates from 1989-1992. Late maturing varieties had significantly higher egg densities (P > 0.01) than early maturing cultivars.*

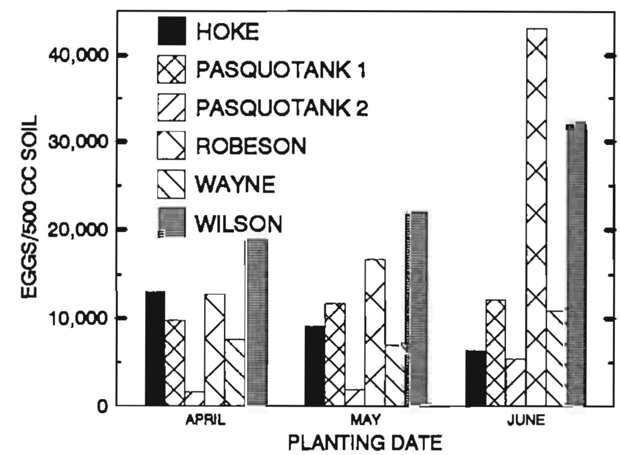

Fig. 3. *Effects of three soybean planting dates and six environments on final egg densities of* Heterodera glycines*/500 cm³ soil from 1989-1992 averaged over four maturity groups. The planting date of soybean was significant (P < 0.01) as was planting date × location.*

(1986-1987) that included nematicides (Table 3, Fig. 4). May-planted soybean yields were superior to June-planted soybean but not markedly so. Nematicide treatments increased soybean yield in the early planting, but not in the late planting (Fig. 4). The yields of MG V soybean were equivalent to those of MG VII soybean in this first series of experiments. Early planting tended to result in increased soybean yields with an optimum planting date in May (Fig. 5) in the second serie of experiments (1989-1992). Early maturing soybean varieties yielded more than late maturing varieties (Fig. 6), but these data are biased since the MG IV variety was not included in late plantings. In both experiments, the first-order interactions for planting date by maturity group, environment by planting date, and environment by maturity group, were significant (Table 3). The presence of these significant interaction terms suggests that local environmental factors play a strong role in affecting soybean yield potential as determined by planting date and/or maturity group.

Discussion

The decline in numbers of soybean cyst nematode eggs and juveniles from April or May until soybean

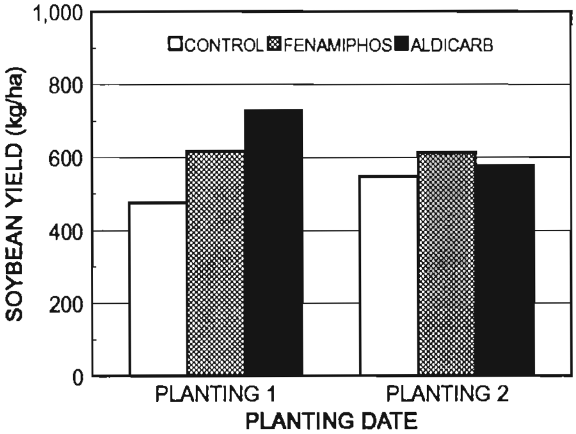

Fig. 4. Influence of two nematicide treatments (fenamiphos applied at 2.35 kg a.i./ha after incorporation in a 30-cm band, and aldicarb applied at 1.68 kg a.i./ha in a 18-cm band) on soybean yield for two planting dates (May vs June) averaged over four environments and two maturity groups. The nematicide × planting date (PD × N) interaction was significant (P = 0.01). Nematicide treatments were significantly (P = 0.01) greater than the control for planting 1, but not for planting date 2 using orthogonal contrasts.

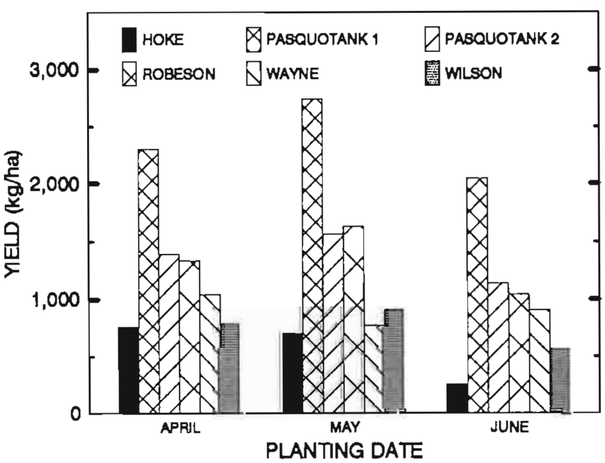

Fig. 5. Soybean seed yield at six environments as affected by planting date, averaged over four MG from 1989-1992. Early plantings were significantly greater (P = 0.0001) than late plantings, but all first-order interactions were significant (P < 0.05).

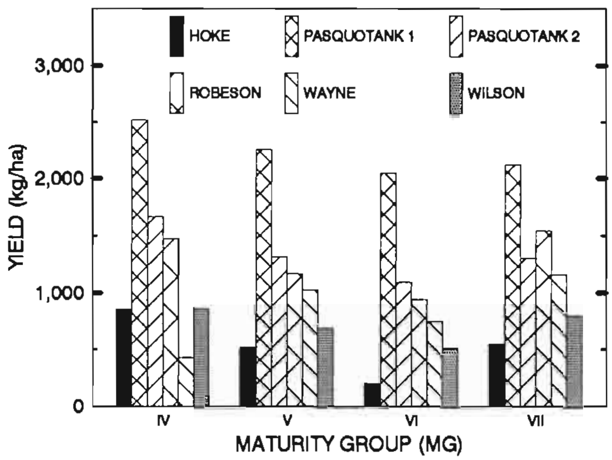

Fig. 6. Influence of soybean maturity group on seed yield at six environments averaged over three planting dates from 1989-1992. Maturity group effects were significant (P = 0.0759), but all first-order interactions were significant (P = 0.05).

planting is consistent with earlier work (Koenning & Anand, 1991; Koenning *et al.*, 1993) but difficult to interpret because of the large variance between planting dates and among years. Although sampling errors may be responsible for much of the observed variation, further research is needed to evaluate environmental factors that may influence attrition of *H. glycines* in the absence of a host. The apparent density dependence of the decline in nematode numbers indicates that biological factors such as predation or parasitism of SCN eggs and juveniles may be important. Density dependent changes in biological populations are generally attributed to biological factors, whereas density independent change is considered to be a result of factors related to the physical environment (Ricklefs, 1976).

Limited data are available on the effects of soybean maturity group on *H. glycines* (Hill & Schmitt, 1989; Koenning *et al.*, 1993; Todd, 1993). Our results establish the predictability of the influence of MG; the later maturing cultivars had consistently higher *H. glycines* levels *(Pf)*. The mechanism involved is relatively simple. Later maturing cultivars have longer growing seasons. The growing season for late maturing cultivars is extended from early to late fall, when soil temperatures have declined and conditions are optimal for *H. glycines* reproduction (Alston & Schmitt, 1988). Data from a Kansas experiment with different MG (Todd, 1993) are difficult to interpret because of the very late plantings used one year. Soybean cultivars are either determinate or indeterminate in regard to flowering. Maturity groups V-VIII are determinate and grown in the Southeastern US, whereas group IV and earlier cultivars grown further North are indeterminate. The lack of significance in the Kansas work may be a result of soybean type, since maturity groups III-V were used in this research.

The influence of planting date on *H. glycines* is more difficult to interpret. Planting date had significant effects on final population densities, but the effects varied from year to year. We noted similar variation in other research conducted over a number of years in a rotation study

(Koenning *et al.*, 1993). A likely explanation of this phenomenon is that different environments associated with planting dates affected nematode population development differently. Evidence for this hypothesis is found in the significant location × planting date interaction ($P < 0.0001$). A second explanation is that date of soybean planting can affect *H. glycines* reproduction rates in another important way. Egg numbers of this nematode usually decline from April to June (Koenning & Anand, 1991; Koenning *et al.*, 1993). The reduction in egg population density associated with late planting limits damage to soybean and thus can encourage higher rates of reproduction for this nematode. Lastly, late planting does shorten the growing season, but not to the extent that an earlier maturity group does. The general rule is that a 3-day delay in planting delays harvest by 1 day, whereas an MG V cultivar matures about 4 weeks before a MG VII cultivar. Thus, while both maturity group and planting date influence the length of the growing season, maturity group has the greater influence. Maturity group also has reproducible effects on nematode population densities because later maturity extends the growing season to a period when conditions usually favor nematode reproduction (Alston & Schmitt, 1988; Koenning *et al.*, 1993). Planting date does not have reproducible effects on nematode population densities because it affects not only the length of the growing season but also density-dependent reproductive rates, and may result in an environment which can be either more or less conducive to reproduction of *H. glycines*.

Soybean yields were highly variable in these experiments because of the range of soil types used, initial *H. glycines* population densities, and local environmental conditions. This aspect of the work was desirable in that we were able to evaluate planting date and MG effects on *H. glycines* in diverse environments. Interpretation of the yield data, however, is problematical because of the presence of significant first order interactions. The critical flowering and pod filling periods for soybean are altered by MG and planting date, thus, most of the variation in planting date and MG effects on soybean yield are a result of periodic moisture stress which is confounded with these factors since these experiments were not irrigated. Selection of optimal soybean planting date or MG is therefore subject to the vagaries of weather in the Southeastern US.

The use of cultural practices to manage *H. glycines* is an interesting and environmentally sound approach. The research described herein demonstrates the feasibility, advantages and disadvantages of using early maturing *H. glycines*-susceptible cultivars or late planting as supplemental tactics for managing this nematode. Earlier maturing cultivars can shift the equilibrium densities of this pest to lower levels, thus boosting soybean yield in subsequent years. Delayed planting can limit damage from *H. glycines* because of nematode attrition but may result in lower yield because of a higher probability of late-season drought stress. Early maturing soybean cultivars may also be more subject to drought stress because of their shorter flowering and pod-filling period, but may escape late-season stress. Early maturing cultivars can be planted late and still provide adequate yields if certain criteria are met. The current management recommendation in North Carolina is to select a cultivar for late planting that will reach 0.9 m in height and still provide a closed canopy (E. J. Dunphy, pers. comm.). This goal can be achieved with many early maturing cultivars, especially with narrow row spacings.

These guidelines allow growers considerable flexibility in that they minimize risk from drought and may spread out planting and harvest operations. Such options are valuable to growers in the Southeastern United States, but their geographic area of application may be limited. Growers in the Northern United States may have less flexibility in planting dates and choice of maturity group. Research on the use of cultural practices to manage *H. glycines* probably should be regionalized (Wrather *et al.*, 1992) and must take into account the local population dynamics and ecology of *H. glycines*.

Much progress has been made in managing soybean yield suppression caused by *H. glycines*. This pathogen still presents significant challenges to growers, researchers, plant breeders, and extension personnel because of its wide distribution and high survival rates. Future research should focus on vulnerable periods in the life cycle of this pest in order to find ways to minimize its reproduction and survival.

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References

ALSTON, D. G. & SCHMITT, D. P. (1988). Development of *Heterodera glycines* life stages as influenced by temperature. *J. Nematol.*, 20 : 366-372.

ANONYME (1985). *SAS/STAT Guide for personal computers, Version 6.* Cary, NC, USA, SAS Institute Inc., 378 p.

BYRD, D. W., Jr., BARKER, K. R., FERRIS, H., NUSBAUM, C. J., GRIFFIN, W. E., SMALL, R. H. & STONE, C. A. (1976). Two semi-automatic elutriators for extracting nematodes and certain fungi from soil. *J. Nematol.*, 8 : 206-212.

FRANCL, L. J. & DROPKIN, V. H. (1986). *Heterodera glycines* population dynamics and relation of initial population to soybean yield. *Pl. Dis.*, 70 : 791-795.

HILL, N. S. & SCHMITT, D. P. (1989). Influence of temperature and soybean phenology on dormancy induction of *Heterodera glycines*. *J. Nematol.*, 21 : 361-369.

HUSSEY, R. S. & BOERMA, H. R. (1983). Influence of planting date on damage to soybean caused by *Heterodera glycines*. *J. Nematol.*, 15 : 253-258.

JENKINS, W. R. (1964). A rapid centrifugal-flotation technique for separating nematodes from soil. *Pl. Dis. Reptr.*, 48 : 692.

KOENNING, S. R. & ANAND, S. C. (1991). Effects of wheat and soybean planting date on *Heterodera glycines* population dynamics and soybean yield with conventional tillage. *Pl. Dis.*, 76 : 301-304.

KOENNING, S. R., ANAND, S. C. & MYERS, G. O. (1992). An alternative method for evaluating soybean tolerance to *Heterodera glycines* in field plot. *J. Nematol.*, 24 : 177-182.

KOENNING, S. R., SCHMITT, D. P. & BARKER, K. R. (1993). Effects of cropping systems on population density of *Heterodera glycines* and soybean yield. *Pl. Dis.*, 77 : 780-786.

RICKLEFS, R. E. (1976). *Ecology*. Portland, Oregon, USA, Chiron Press, 861 p.

SCHMITT, D. P. (1991). Management of *Heterodera glycines* by cropping and cultural practices. *J. Nematol.*, 23 : 348-352.

SCHMITT, D. P. & NELSON, L. A. (1987). Chemical control of selected plant-parasitic nematodes in soybeans double-cropped with wheat in no-till and conventional tillage systems. *Pl. Dis.*, 71 : 323-326.

SCHMITT, D. P. & RIGGS, R. D. (1989). Population dynamics and management of *Heterodera glycines*. *Agric. Zool. Rev.*, 3 : 253-269.

TODD, T. C. (1993). Soybean planting date and maturity effects on *Heterodera glycines* and *Macrophomina phaseolina* in southeastern Kansas. *J. Nematol.*, 25 : 731-737.

WRATHER, J. A., ANAND, S. C. & KOENNING, S. R. (1992). Cultural practices for management of *Heterodera glycines*. *In* : Riggs, R. D. & Wrather, J. A. (Eds.). *Biology and management of the soybean cyst nematode*. St. Paul, MN, USA, APS Press : 125-131.