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Influence of Planting Date on Population Dynamics and Damage Potential of *Pratylenchus brachyurus* on Soybean[1]

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Abstract: Planting date was used as a variable to determine the effects of time and different environmental conditions on the population dynamics and damage potential of *Pratylenchus brachyurus* on soybean at two locations in North Carolina. An initial population slightly less than the damage threshold (275 nematodes/500 cm^3 soil) was used to minimize the influence of host damage on this nematode's population dynamics and to gain greater precision in characterizing factors which influence the damage potential of *P. brachyurus* to soybean. Equivalent nematode numbers generally resulted in greater yield suppression of soybean in early plantings. Early planting of soybean also resulted in greater ($P = 0.01$) population densities of *P. brachyurus* at midseason which often persisted until soybean harvest. Length of time for reproduction and intraspecific competition occurring when soybeans were stunted by the nematode were the most important factors influencing the population dynamics of *P. brachyurus*.

Key words: *Glycine max,* lesion nematode, control, yield suppression, microplots, ecology.

Pratylenchus brachyurus (Godfrey) Filipjev and Schuurmans-Stekhoven is pathogenic to soybean, *Glycine max* (L.) Merr. (11,17,19,20). Distributed throughout most of the southeastern United States (3,16), the nematode has suppressed yields up to about 31% (19). This nematode's effect on soybean yield may be altered by soil type, initial population density (Pi), cultivar, and environment (17,20). In a 2-year experiment with the *P. brachyurus* sensitive cultivar Forrest, significant yield suppression occurred at a relatively low Pi one year on a Norfolk loamy sand soil, but not the next year at a higher Pi (19); yield suppression occurred both years in a Lakeland sand. Damage to soybean by *P. brachyurus* tends to be erratic, probably because of variations in environmental conditions between locations and seasons (17,19).

Pratylenchus brachyurus has a relatively high temperature optimum (28–30 C) (1,11,15,16) which may influence its damage potential on soybean (11). Soybeans may be planted in North Carolina any time between 1 May and 15 July, although most are planted in mid May or mid to late June when double cropped with small grains. Because optimum soil temperatures for *P. brachyurus* activity (1,11,15,16) normally occur relatively late in the growing season, planting date could have a major effect on the damage potential of this nematode to soybean.

The maturity group V soybean cultivar Forrest is highly susceptible to *P. brachyurus* (19). Forrest is widely planted because of its high yield potential, drought tolerance, and resistance to *Heterodera glycines* Ichinohe (races 1 and 3) and *Meloidogyne incognita* (Kofoid and White) Chitwood. These favorable characteristics often result in Forrest being planted earlier or later than the currently recommended period of 10 to 20 May in North Carolina.

Integrated pest management systems require reasonably accurate prediction of yield losses from pests, including the impact of climate, cropping system, cultivar, and other factors which can influence pest populations and their damage potential to crops. The general goal of this research was to provide such information for *P. brachyurus* on soybean. Specific objectives of our research were 1) to determine the effects of planting date on the damage potential of *P. brachyurus* on soybean and 2) to identify environmental conditions which influence the damage potential of *P. brachyurus* to soybean.

Materials and Methods

Experiments were conducted in 1981 and 1982 at two locations, Central Crops Re-

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TABLE 1. Growth of soybean as influenced by planting date and *Pratylenchus brachyurus* at Central Crops Research Station (CCRS) and at Border Belt Tobacco Research Station (BBTRS).

		Plant height (cm)							
		September 1981*				July 1982†			
Planting date‡	Inoculum	CCRS	SE	BBTRS	SE	CCRS	SE	BBTRS	SE
1	0	92.3	26.7	106.2	37.2	98.5	44.4	101.5	36.9
	275	88.0	24.3	95.7	25.6	93.7	10.3	95.7	19.7
2	0	98.0	27.2	113.0	22.4	96.2	13.4	104.4	12.5
	275	91.0	26.7	112.1	33.7	97.5	15.9	100.2	39.0
3	0	61.9	27.8	98.0	16.8	55.7	6.3	70.7	5.9
	275	70.1	17.9	91.9	21.5	52.3	22.1	69.8	11.9
4	0			66.3	23.4			31.5	6.4
	275			68.2	21.4			28.3	20.3

* Data are means of eight replicates, SE = standard error.

† Data are means of four replicates. Inoculum was infested soil and root fragments containing eggs, juveniles, and adults. Plant height suppression by *P. brachyurus* within that planting date, location, and year was significant ($P = 0.05$) in split-plot ANOVA.

‡ Planting dates: BBTRS—1981: 1 = 1 May, 2 = 22 May, 3 = 12 June, 4 = 3 July; CCRS—1981: 1 = 2 May, 2 = 30 May, 3 = 27 June; BBTRS—1982: 1 = 30 April, 2 = 22 May, 3 = 11 June, 4 = 2 July; CCRS—1982: 1 = 1 May, 2 = 29 May, 3 = 26 June.

search Station (CCRS) near Clayton, North Carolina, and approximately 150 km south at the Border Belt Tobacco Research Station (BBTRS) near Whiteville, North Carolina. The soil type at CCRS was a Norfolk loamy sand (87% sand, 9% silt, 4% clay) and at BBTRS, a Goldsboro sandy loam (69% sand, 27% silt, 4% clay).

A population of *P. brachyurus* originally isolated from soybean was cultured on soybean in the greenhouse for use as inoculum. Nematode inoculum was prepared from infected fibrous roots. Inoculum was quantified by macerating five subsamples of roots in 75 ml water in a blender for 30 seconds, increasing the volume to 500 ml, counting three 10-ml aliquants, and calculating the number per weight of infected root. Roots were then cut into 2.5-cm pieces, thoroughly mixed, divided into aliquants in order to obtain about 275 *P. brachyurus*/500 cm^3 inoculum and mixed with soil for transport to the experimental sites. The inoculum density was selected because it is the level at which some damage and yield suppression occurs (18). Equal quantities of noninfected roots were used as inoculum in control plots.

Microplots (5) were infested at planting by mixing inoculum into the soil to a depth of 15 cm. Forrest soybean seeds were inoculated with a commercial preparation of *Rhizobium japonicum* (Kirchner) Buchanan before planting, and 1,000 chlamydospores of *Glomus macrocarpus* Tul. and Tul. were added to each plot.

Treatments were arranged in a split-plot design with planting dates as whole plots and nematode inoculum (0 or 275 ± 27/500 cm^3 soil) as subplots. Microplots were fumigated with 50 g methyl bromide/m^2 and limed and fertilized according to soil test recommendations. The first set of plots at CCRS was infested and planted on 2 May 1981 and 1 May 1982, and succeeding sets of plots 28 and 56 days later. At BBTRS, infestation and planting of the first set of plots took place on 1 May 1981 and 30 April 1982 and succeeding sets of plots 21, 42, and 63 days later. There were eight replications for each planting date–inoculum combination in 1981 and four replications in 1982.

Microplots were sampled for nematodes periodically (numbers varied because of different planting dates) during the growing season by taking a sufficient number of 2.5-cm-d cores to a depth of 15–20 cm to secure 250 cm^3 of soil. Resulting holes were filled with steamed soil. Nematodes were extracted from the 250-cm^3 soil samples by elutriation and centrifugation (4) and from roots by Seinhorst mist (4) for 7 days. Plant height and phenology (6) were recorded at sampling dates, and the numbers of nodes on the main stem of plants were recorded in 1982. Mean soil temperature at 15 cm in the plots was recorded continuously with

TABLE 2. Mean number of nodes on the main stem of soybean as influenced by planting date and *Pratylenchus brachyurus* (Pb) in 1982 at Central Crops Research Station (CCRS) and at Border Belt Tobacco Research Station (BBTRS).

Planting date‡	CCRS*				BBTRS*			
	Control		Pb†		Control		Pb†	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	15.2	0.3	14.5	0.6	14.8	0.5	13.0	1.2
2	17.0	0.4	15.8	0.5	15.3	0.5	14.0	0.6
3	15.0	0.3	14.3	0.3	15.5	0.9	14.3	0.6
4					13.8	0.3	13.5	0.3

* All data are means of four replications.
† *P. brachyurus* (Pb) suppressed the number of nodes on the main stem ($P = 0.01$).
‡ Planting dates: See note, Table 1.

a micrologger (Campbell Scientific Inc., Logan, Utah).

Plant data were subjected to analysis of variance (ANOVA) for a split-plot design using orthogonal contrasts for equally spaced planting dates. Regression analyses were used to compare mean yields with planting dates and nematode inoculum. Nematode numbers were transformed to $\log_{10}(n + 1)$ and subjected to ANOVA for a randomized complete block design with orthogonal polynomial contrasts for equally spaced planting dates. Regression analyses were utilized to compare mean rates of nematode increase.

RESULTS

Soybean growth and yield: The relationship between soybean growth, as measured by plant height, and planting date was adequately described by a quadratic model ($P = 0.01$) with plant height being considerably less after the second planting date (Table 1). Differences in plant growth between *Pratylenchus brachyurus*-infested and control plots were slight. Nematode-inoculated plants had fewer nodes on the main stems than did the noninoculated controls at both locations in 1982 (Table 2).

Plant phenology (6) was altered by planting date (Fig. 1A–D). Later planting resulted in delayed onset of flowering; nevertheless, all plantings reached harvest maturity within a 2-week period. *P. brachyurus* delayed the onset of flowering. Infected plants turned yellow and defoliated earlier than the controls.

The overall relation between soybean yields and planting date was adequately described by a quadratic model ($P = 0.01$) (Fig. 2). *P. brachyurus* did not have a significant impact on soybean yields at CCRS in 1981, although yield was suppressed slightly for the first planting date. Yield was suppressed by nematodes at BBTRS in 1981 ($P = 0.01$) with greatest effects in the first and third planting dates ($Y = 679.7 - 75.9n + 249.9p - 276.8p^2 + 47.5p^3 + 45.7pn$; where p = planting date and n = nematode inoculum; $R^2 = 0.98$; $P = 0.03$). Yields were suppressed at both locations in 1982, with yield suppression occurring in the first and second plantings at CCRS and the first planting at BBTRS. CCRS 1982, $Y = 740.1 - 151.9n - 135.8p - 65.9p^2 + 90.0pn$; $R^2 = 0.99$, $P = 0.11$. BBTRS 1982, $Y = 578.6 - 128.9n + 313.8p - 280.0p^2 + 45.6p^3 + 45.8pn$; $R^2 = 0.99$, $P = 0.015$. There was a planting date–nematode interaction ($P = 0.10$–$P = 0.01$) in both years at both locations. Delayed planting of soybean generally resulted in lessened effect by *P. brachyurus* on yield, although environmental influences also affected this interaction (Figs. 3A, B, 4A–D).

Population dynamics of Pratylenchus brachyurus: The majority of nematodes were always extracted from root fragments. Correlations of the root fraction of the population with the total population (sum of soil and root fractions) ($r = 0.96$) were always significant ($P = 0.01$) and accounted for most of the variation within samplings. Soil populations were poorly correlated with the total population ($r = 0.16$–0.59; $P = 0.10$–0.03) and accounted for less variation. Eggs of *P. brachyurus* were rarely recovered from soil.

Nematode population densities increased after planting until soybeans

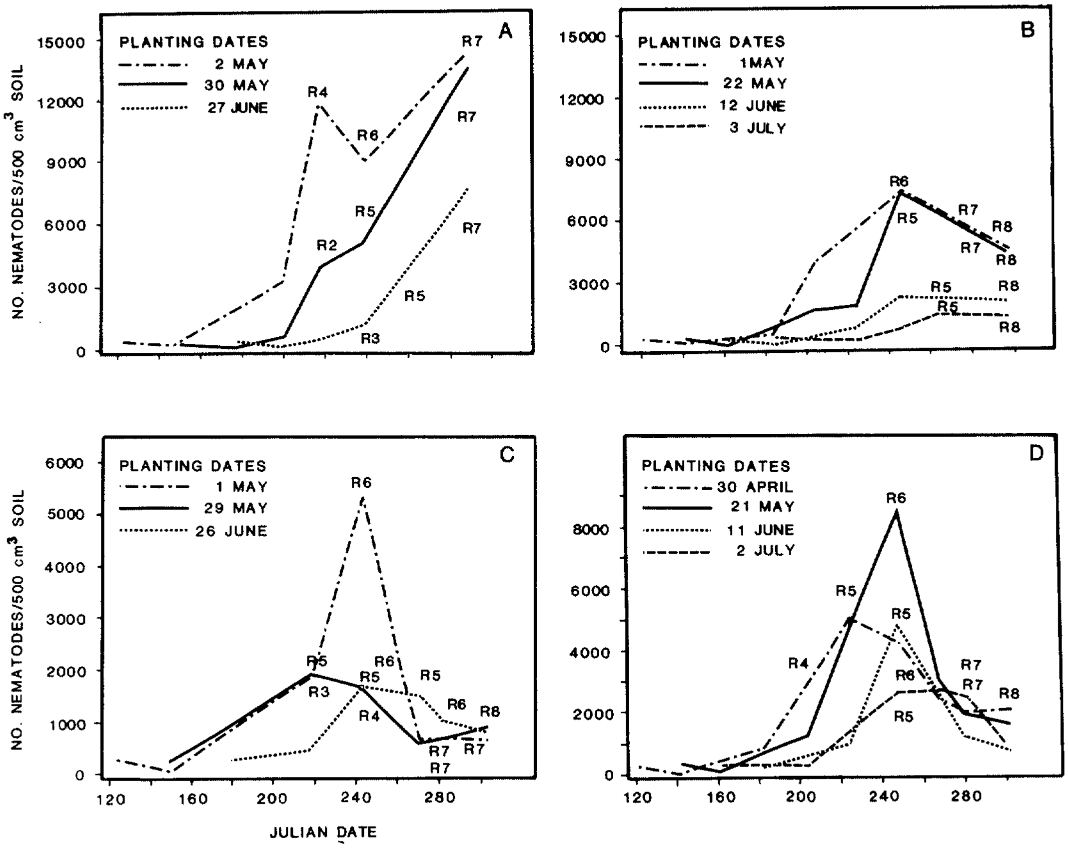

FIG. 1. Influence of soybean planting date on plant phenology and the population densities of *Pratylenchus brachyurus* in soil and roots per 500 cm³ soil at different sampling dates. A) Central Crops Research Station (CCRS) in 1981. B) Border Belt Tobacco Research Station (BBTRS) in 1981. C) CCRS—1982. D) BBTRS—1982. The letter–number (e.g., R3) coding on graph is the designation for stage of soybean growth (6).

reached physiological maturity (R7) at CCRS (Fig. 1A). At BBTRS, where suppression of soybean growth and yield occurred (Tables 1, 3), much lower population maxima were achieved for all planting dates, compared to CCRS, and the nematode populations had declined before the R8 plant growth stage (Fig. 1B). Late planting resulted in less nematode population increase than did early planting (Fig. 1A, B).

Yield and growth suppression of soybean by *P. brachyurus* were generally more pronounced in 1982 than in 1981 at both locations. Damage to soybean resulted in lower nematode numbers at both locations in 1982 which confounded the effects of planting date on nematode population dynamics. Nematode populations declined before soybean physiological maturity (R7), in some instances drastically, except in late plantings (Fig. 1C, D). Nematode population increase was influenced similarly by the planting date of soybean in 1982 (Fig. 1C, D).

Relation of environment to plant and nematode dynamics: Environmental conditions differed between years and locations. In 1981 the early growing season at CCRS was extremely hot and dry with soil temperatures exceeding 30 C for extended periods (Figs. 3A, 4A). BBTRS received adequate to high rainfall early in the growing season, and soil temperatures were lower than at CCRS (Figs. 3A, 4B). Soil temperature was generally lower at both locations in 1982 than in 1981 (Fig. 3B). CCRS received high rainfall early in the 1982 season, whereas rainfall at BBTRS was generally adequate to slightly below adequate during this period (Fig. 4C, D). In both years, soybeans planted in May generally

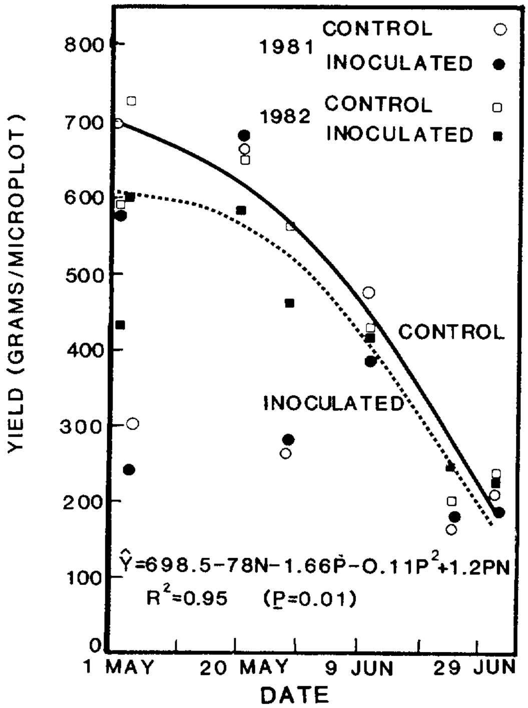

FIG. 2. Planting date and *Pratylenchus brachyurus* inoculum impact on soybean yield at Central Crops Research Station (CCRS) and Border Belt Tobacco Research Station (BBTRS). Model is based on mean soybean yields with eight replications in 1981 and four replications in 1982. The 1981 yields at CCRS were adjusted to 1982 levels to generate the models, curves, and R^2 because of severe drought stress in 1981 [adjusted 1981 yield = 1981 yield + (1982y − 1981y) was calculated for each planting date].

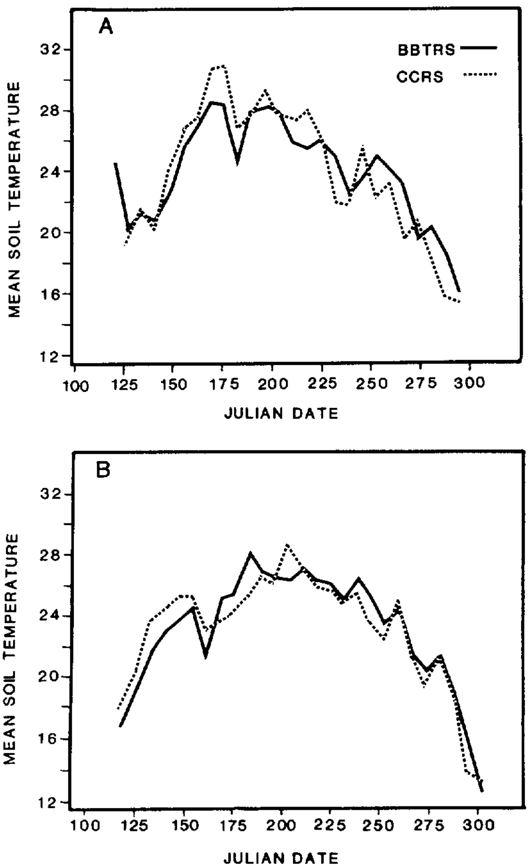

FIG. 3. Mean soil temperatures at 15 cm deep at the Border Belt Tobacco Research Station (BBTRS) and the Central Crops Research Station (CCRS). A) 1981. B) 1982.

received adequate rainfall from the onset of flowering to R5–6 (pod filling) (Fig. 4A–D). Rainfall was always less than adequate in the latter part of the soybean reproductive stages especially for later plantings (Fig. 4A–D).

Yield was generally suppressed by *P. brachyurus* when soybeans were planted during high rainfall (Table 3; Fig. 4A–D). Conversely, no growth–yield suppression occurred when the soil was hot and dry.

Discussion

Soybean yield suppression by *Pratylenchus brachyurus* became limited as soybean planting was delayed. The opposite was expected since *P. brachyurus* has a temperature optima of 28–30 C (1,11,15,16). These relatively high soil temperatures commonly occur in late June through August (8). Additionally, soil temperatures were near-er the optimum (1,11,15,16) in 1981 when yields were not affected at CCRS. Damage potential and reproductive activity may not have the same relationship to temperature. For example, suppression of 'Hood' and 'Pickett' soybean root weight by *P. brachyurus* was greater at 21 C than at 29 C (11).

Soil moisture is an important component of this pathosystem and may be very important in influencing *P. brachyurus* damage to soybean. Yield and growth suppression of soybean by this pest occurred when plants received high rainfall.

Root penetration by *Pratylenchus* spp. may be favored by moist (−0.05 to −0.30 bars) soil (10,14). Infection of peanut pods by *P. brachyurus* was increased when irrigation was used to maintain soil moisture near field capacity (7). High soil moisture, however, may suppress soybean root

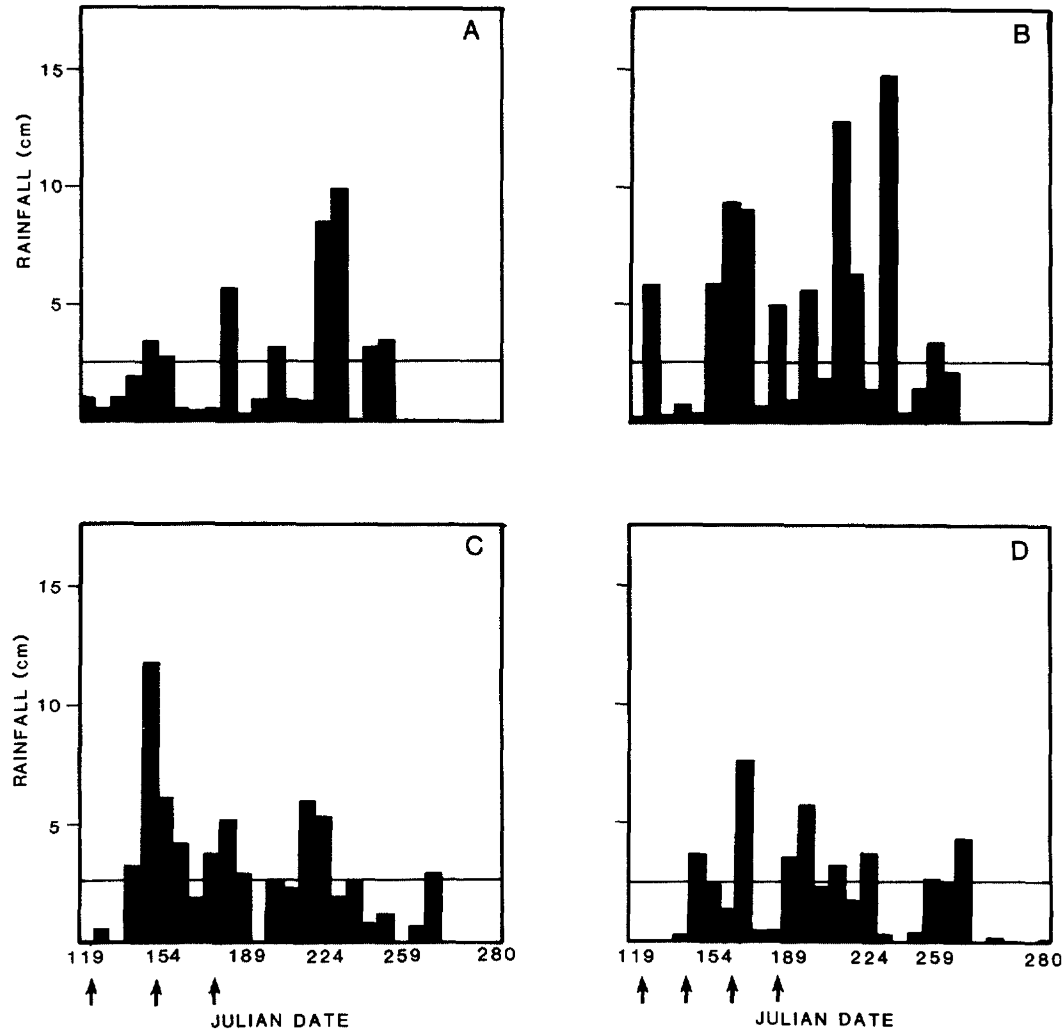

FIG. 4. Weekly precipitation. A) Central Crops Research Station (CCRS) in 1981. B) Border Belt Tobacco Research Station (BBTRS) in 1981. C) CCRS—1982. D) BBTRS—1982.

growth by depressing oxygen tensions. Excessive irrigation results in shallow soybean root systems (12). Thus, the mechanism of injury could possibly involve interactive effects of root growth suppression by excessive soil moisture and nematode feeding. These soybean plants would not be able to recover enough to achieve their maximum yield potential in the presence of *P. brachyurus*. Irrigation experiments, however, are necessary to separate causal relationships between nematode damage and soil moisture stress.

Planting date, which determined the time available for nematode reproduction, was the most important variable influencing the population dynamics of *P. brachyurus* in our experiments. Early planting generally resulted in high nematode population densities. Greater root biomass should be associated with early plantings giving the nematode a larger food base.

The results presented here have important implications to phytonematology when viewed in terms of population ecology and nematode reproductive strategies. The concept of r-strategists and K-strategists has only recently been considered in plant pathology (2,20) and nematology (9). Nevertheless, examination of our results in the context of such reproductive strategies could provide new insight into the population dynamics of *P. brachyurus* and other plant-parasitic nematodes. K-strategists are organisms whose population dynamics are dominated by the environmental carrying capacity and which have relatively low rates of reproduction together with special adaptations for survival. The r-strategists are organisms with high rates of reproduction which rely on the associated high fecundity to offset high mortality. *P. brachyurus* can be considered K selected compared to nematodes with a high rate of reproduction such as *Meloidogyne* spp. Its population size would thus be controlled by the carrying capacity of its ecological niche. Therefore, *P. brachyurus* population models should include a damage function when this nematode is pathogenic to the host. For example, the population dynamics model for *Pratylenchus hexincisus* on corn was more sensitive to changes in Pi than to different sets of weather data (13).

Soybean diseases caused by *P. brachyurus* are influenced by Pi, planting date, and environment (19). Since Pi is generally the most important variable in soybean disease caused by *P. brachyurus,* factors which influence Pi are important in predicting crop damage. Thus, selection of planting dates and other management factors which influence crop growth can be manipulated to avoid significant nematode injury to the soybean crop.

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