CONTROL OF NEMATODES IN PEANUT AND SOYBEAN WITH METAM-SODIUM

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ABSTRACT

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The efficacy of Busan® 1020 (32.7% metam-sodium) for control of *Meloidogyne arenaria* in 'Florunner' peanut (*Arachis hypogaea*) was studied for 2 years in field experiments in southeast Alabama. Pre-plant in-row applications of Busan 1020 at rates of 93-280 L/ha resulted in increased yields. The relation between yield (Yp) in kg/ha and Busan 1020 application rates (x) in L/ha was (R^2=0.95**) according to the normal distribution equation: $Yp=3371e^z$, where $z=(x-216)^2/(-191896)$. Busan 1020 treatments reduced numbers of *M. arenaria* juveniles in soil in a non-linear manner both years of the study. The effects of preplant applications of Busan 1020 on soybean (*Glycine max*) nematodes were studied for one year in a field in southwest Alabama. There was a linear relation (R^2=0.98**) between 'Ransom' soybean yield (Ys) in kg/ha and Busan 1020 rates in the range of 0-234 L/ha; the relation was: $Ys=327.35+1.77x$. Busan 1020 had no effect on juvenile populations of *H. glycines* in soil; however, application rate was related (R^2=0.99**) to numbers of *M. incognita* juveniles (Ji) in 100 cm^3 soil by the normal function: $Ji=519e^w$, where $w=(x-103)^2/(-34144)$.

Additional key words: chemical control, fumigants, nematicides, carbamates, Vapam, pest management, root-knot nematodes, soybean cyst nematodes.

RESUMEN

Rodríguez-Kábana, R., D. G. Robertson, y P. S. King. 1987. Uso del metam-sodium para combatir nematodos en el maní y la soya. Nematrópica 17:31-43.

Se estudió por dos años la eficacia de Busan®1020 (metam-sodium 32.7%) para combatir *Meloidogyne arenaria* en el maní (*Arachis hypogaea*) 'Florunner' en un campo en el sureste de Alabama. Inyecciones de presiembra en el surco con Busan 1020 a dosis de 0-280 L/ha aumentaron la producción de maní. La relación entre los rendimientos de maní (Yp) en kg/ha y las dosis de Busan 1020 (x) en L/ha quedó definida (R^2=0.95**) por la función normal: $Yp=3371e^z$ en la cual $z=(x-216)^2/(-191896)$. Los tratamientos con Busan 1020 disminuyeron el número de larvas de *M. arenaria* en el suelo de acuerdo con modelos curvilineos en los dos años del estudio. Se estudiaron también aunque sólo por un año los efectos de los tratamientos de presiembra con Busan 1020 sobre los nematodos de la soya (*Glycine max*). La relación entre la producción de soya (Ys) en kg/ha y las dosis de Busan 1020 resultó ser linear y positiva (R^2=0.98**) quedando descrita por la ecuación: $Ys=327.35+1.77x$. Los tratamientos con Busan 1020 fueron inefectivos contra las poblaciones de larvas de *Heterodera glycines* en el suelo aunque no fue así para con las de *M. incognita* con las cuales el número de larvas en 100 cm^3 de suelo (Ji) y las dosis de Busan

1020 quedaron relacionadas (R^2=0.99**) por la función normal: Ji=519e^w, en la que w=(x–103)²/(–34144).
Palabras claves adicionales: combate químico, fumigantes, nematicidas, carbamatos, Vapam, manejo de plagas, nematodos agalladores, nematodo enquistador de la soya.

INTRODUCTION

Peanut (*Arachis hypogaea* L.) and soybean (*Glycine max* [L.] Merr.) are the most important legume crops of the southeastern United States. Nematode damage is one of the principal limiting factors in the production of these crops (7,8,14,15,25,26,28). The main nematode problems of peanut in the region are caused by *Meloidogyne* spp. (6,13,15). The peanut root-knot nematode (*M. arenaria* [Neal] Chitwood) is the most economically important species in Alabama and it is widespread in the soils of the peanut-growing counties (6). Yield losses to this nematode are so severe (27) that production of the crop is not possible without the use of nematicides and adequate rotation systems (12,16,17,21). In the past the use of the fumigant nematicides dibromochloropropane (DBCP) and ethylene dibromide (EDB) provided an economical method for controlling *M. arenaria* in the crop (18); however, these halogenated hydrocarbons were recently banned for use by farmers by the U.S. Environmental Protection Agency. While other nematicides are available, their cost is high and in most cases they are not as effective or economical as EDB or DBCP (17).

Soybean production in Alabama is also limited by damage from *Meloidogyne* spp., the cyst nematode (*Heterodera glycines* Ichinohe), and other nematodes (25,26,30). In contrast to peanut, a number of soybean cultivars have been developed in the southeastern U.S.A. with a degree of tolerance to some *Meloidogyne* spp. and resistance to several races of *H. glycines* (8,20,30); however, it has been shown that yields of even the most nematode tolerant cultivars can be significantly improved by the use of nematicides (9,11,20,30). Thus, there is a need to develop effective and economical nematicide treatments for both soybean and peanut. Sodium N-methyldithiocarbamate (metam-sodium) has been used as a broadspectrum biocide for many years, and applications of high dosages (>300 L/ha) of this material resulted in good control of nematodes, weeds, fungal pathogens, and other pests (1). More recently, there has been interest in determining whether low rates (<200 L/ha) of metam-sodium can be used to control nematodes (4,5). This paper presents results from a 2-year study on the efficacy of low rates of a metam-sodium formulation (Busan 1020) for control of nematodes in peanut and of a one-year experiment in soybean.

MATERIALS AND METHODS

The efficacy of Busan 1020 for control of *M. arenaria* in 'Florunner' peanut was studied for 2 years in a field at the Wiregrass Substation near Headland, Alabama. Busan 1020 is a liquid formulation manufactured by Buckman Laboratories (Memphis, TN) and contains 32.7% sodium N-methyldithiocarbamate (metam-sodium). The field had been in peanut continuously for the preceeding 8 years with hairy vetch (*Vicia villosa* Roth) planted every winter as a cover crop. The soil was a Dothan fine sandy loam (Plinthic Paleudult) with less than 1.0% organic matter and pH 6.2-6.4. Busan 1020 was applied in the row to a depth of 35-40 cm using a single chisel plow per row, one (1985) or two (1986) weeks before planting in early May. Each year Busan 1020 was applied at rates of 0, 93, 140, 187, 234 and 280 L/ha. A treatment of 16.8 L EDB/ha applied in the same manner as Busan 1020 was included each year to serve as a standard. Soil moisture at the time of application each year was approximately 60% of field capacity. Each treatment was represented by 8 replications (plots) within a randomized complete block design. A plot was 10 m long and 2 rows (each 0.9 m) wide. Cultural practices, control of foliar diseases, insects, and weeds were as recommended for the area (2). The field was irrigated as needed to avoid water stress of the plants.

Soil samples for nematode analysis were collected from each plot 2 weeks before harvest to coincide with the period of maximal population development of *M. arenaria* in the crop (24). Preplant samples indicated that juvenile populations in the field were at less than 10/100 cm^3 soil. A soil sample consisted of 16-20 2.5-cm-diam cores per plot taken to a depth of 20-25 cm from the root zone of the plants. Cores were collected from both rows at approximately 0.3-0.5 m spacings. Cores from each plot were composited and a 100-cm^3 subsample was used to assess nematode numbers with the "salad bowl" incubation method (19). Yield data were obtained by harvesting the entire plot area at maturity of the crop.

The effect of Busan 1020 applications on soybean nematodes was studied with an experiment in 1985 in a field near Elberta, Alabama. The experiment was designed to provide supporting data for the peanut study. The field was infested with *M. incognita* (Kofoid & White) Chitwood and races 3 and 4 of *H. glycines*. The field had been in soybean and a winter cover crop of wheat (*Triticum aestivum* L.) or annual ryegrass (*Lolium* spp.) for the preceeding 6 years. The soil was a Norfolk fine sandy loam (Typic Paleudults) with less than 1.0% organic matter and pH=6.4. Busan 1020 was applied 2 weeks before planting of 'Ransom' soybean as described for the peanut experiments. Plots were 6 m long and 2 rows (each 0.8 m) wide. Application rates were 0, 93, 187, and 234 L Busan 1020/ha. We chose the 'Ransom' cultivar because it is a good host for the nematodes in the field. The susceptibility of this cultivar to nematode attack would permit us to detect any yield response to the treatments independently of any genetic tolerance to the nematodes in the cultivar. The number of replications (plots)/treatment and the statistical design were as for the peanut study. Soil moisture at application time was approximately 60% of field capacity. Soil samples for nematodes were taken in mid-September to coincide with the period of maximal population development of *M. incognita* (22); preplant samples from the field contained less than 20 juveniles per 100 cm^3 soil of either *M. incognita* or *H. glycines*. The sampling procedure was the same as for peanut. Cultural practices and control of weeds, insect, and foliar diseases were according to recommendations for the area (3). Yield data were obtained by harvesting the entire plot area in mid-November at maturity of the crop.

All data were analyzed following standard procedures for analysis of variance (29); regression analysis and curve fitting by least square methods were also by standard procedures (10,29). Fisher's least significant differences (L.S.D.) were calculated (29) and are included in all tables. Unless otherwise stated all differences referred to in the text were significant at the 5% or lower level of probability.

RESULTS

Peanut. Rainfall distribution data for the two years of the experiment are presented in Table 1. Applications of Busan 1020 increased yields in both years according to a similar pattern of response (Table 2). Yields in 1985 were higher than in 1986, but the treatment x year interaction was not significant. The relation between yield (Yp) in kg/ha and rate of Busan 1020 (x) in L/ha for the 2-year averages (Fig. 1) was described ($R^2=0.98^{**}$) by the normal distribution equation function:

$$Yp = 3371e^{(x-216)^2/(-191896)}$$

Table 1. Rainfall distribution during the 1985 and 1986 peanut growing seasons at the Wiregrass Substation, near Headland, Alabama.

	Rainfall in cm	
Month	1985	1986
May	10.69	12.16
June	7.03	6.83
July	14.22	11.94
August	14.73	12.67
September	5.53	5.05

Table 2. Effects of pre-plant applications of Busan® 1020 (32.7% metam-sodium) on 'Florunner' peanut yield and *M. arenaria* juvenile populations in a 2-year study conducted in a field near Headland, Alabama.

Busan 1020 rate (L/ha)	1985 Juveniles per 100 cm^3 soil	1985 Yield (kg/ha)	1986 Juveniles per 100 cm^3 soil	1986 Yield (kg/ha)
0	118	3072	28	2265
93	75	2967	1	3200
140	63	3149	0	3228
187	44	3453	4	3472
234	43	3691	2	3119
280	38	3190	0	3309
EDB-90[z]	57	3632	2	2875
LSD (P=0.05):	52	348	24	445

[z]EDB-90 was applied pre-plant at 16.83 L/ha.

The EDB treatment resulted in significant yield increases each year. Yield responses to Busan 1020 applications were equivalent or superior to the EDB treatment when applied at rates of 187 L/ha or higher.

Juvenile populations of *M. arenaria* in 1986 were lower than in 1985; analysis of the data for the 2 years revealed a significant treatment x year interaction. The relation between numbers of juveniles in 100 cm^3 soil (Ja) and Busan 1020 rates for 1985 followed (R^2=0.98**) the parabola (Fig. 2):

$$Ja = 118.340 - 0.551x + 0.001x^2$$

In 1986, numbers of juveniles were so reduced by the treatments and the dry weather conditions that the relation between their numbers and Busan 1020 rates followed a sharp hyperbolic decline described (R^2=0.97**) by (Fig. 2):

$$Ja = 1.484 + 2.606/x$$

In 1985, the relation between peanut yield and numbers of *M. arenaria* juveniles in 100 cm^3 soil was significant (R^2=0.78*) and followed the model:

$$Yp = Ja/(0.0004Ja + 0.0038)$$

A relation between yields and juveniles numbers for 1986 could not be established because of the restricted size of the nematode population.

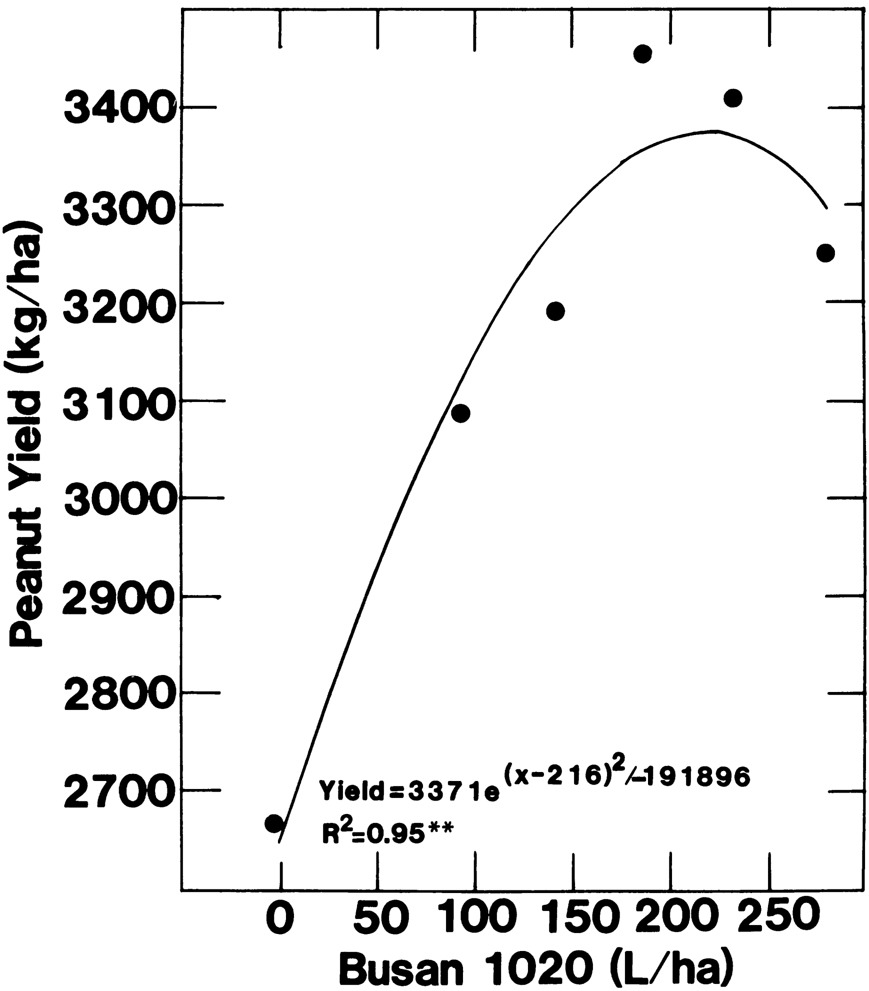

Fig. 1. 'Florunner' peanut yields and pre-plant application rates of Busan 1020 (32.7% metam-sodium) from a 2-year study in a field infested with *M. arenaria*.

Soybean. Rainfall during the soybean growing season (May-Nov.) was adequate and averaged 21 cm per month. Data from this experiment are presented in Table 3. Applications of Busan 1020 increased yields. The relation between yield (Ys) in kg/ha and application rate was linear (R^2=0.98**) and described by (Fig. 3):

$$Ys = 327.35 + 1.77x.$$

Yields from EDB-treated plots were higher than from any of those

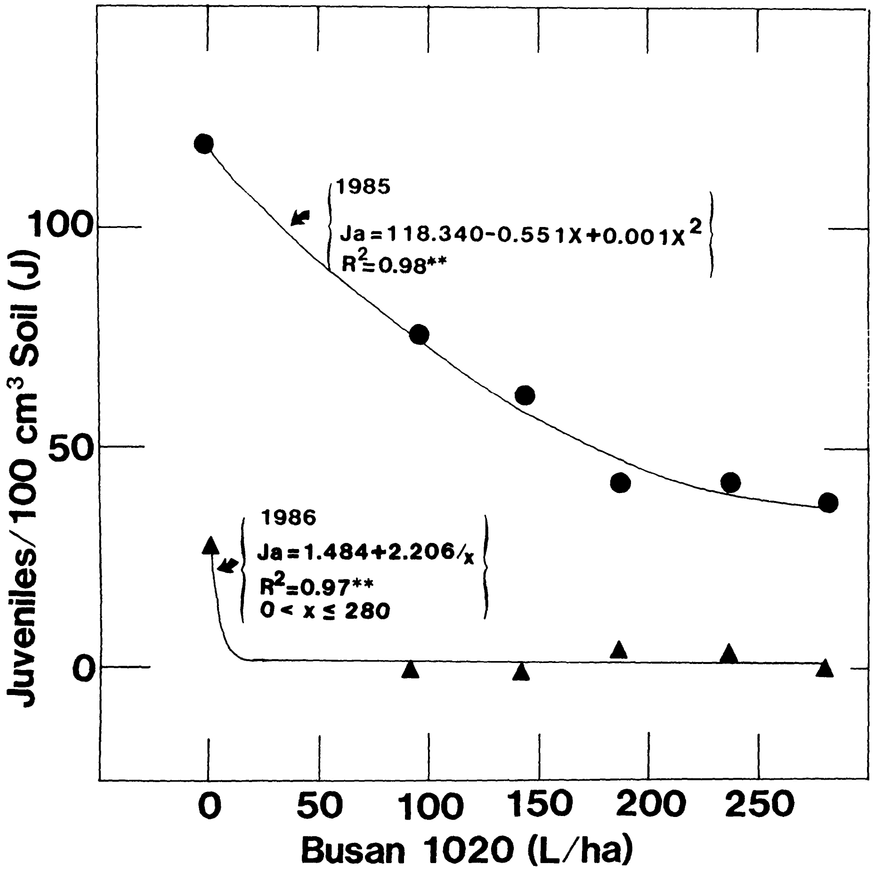

Fig. 2. Relation between numbers of *M. arenaria* juveniles in soil and pre-plant application rates of Busan 1020 (32.7% metam-sodium) in a 2-year experiment in a field with 'Florunner' peanut near Headland, Alabama.

treated with Busan 1020. *M. incognita* juvenile populations in soil were lowest in EDB-treated plots. The relation between Busan 1020 rates and numbers of *M. incognita* juveniles in 100 cm^3 soil (Ji) was described (R^2=0.99**) by (Fig. 4):

$$Ji = 519e^{(x-103)^2/(-34144)}$$

No treatment with Busan 1020 reduced soil populations of *H. glycines* juveniles; however, the 234-L rate resulted in increased numbers of the nematode, as did the EDB treatment. No clear pattern of response to Busan 1020 applications was detected for *H. glycines* juveniles in soil. Also, no clear relation could be established between numbers of juveniles in soils of either *M. incognita* or *H. glycines* and soybean yield.

Table 3. Effects of pre-plant applications of Busan® 1020 (32.7% metam-sodium) on 'Ransom' soybean yield and juvenile populations of *M. incognita* and *H. glycines* in soil in a 1985 experiment in a field near Elberta, Alabama.

Busan 1020 Rate (L/ha)	*M. incognita* juveniles per 100 cm^3 soil	*H. glycines* juveniles per 100 cm^3 soil	Yield (kg/ha)
0	381	197	343
93	512	269	457
187	428	217	686
233	312	333	732
EDB-90[z]	206	366	1189
LSD (P=0.05):	152	98	196

[z]EDB-90 was applied pre-plant at 16.83 L/ha.

DISCUSSION

Results from the peanut experiments demonstrated that use of Busan 1020 can result in substantial yield increases and reductions in *M. arenaria* juvenile populations when applied at rates considerably below those recommended for "sterilization" of soils (1). The pattern of yield response to rates of the chemical suggests that there is a maximal possible yield recoverable through the use of the fumigant. The model chosen to describe the relation between yield and rates is a normal equation predicting a maximal yield response to applications of 215.7 L/ha of Busan 1020, equivalent to 70.5 L/ha of metam-sodium, the active ingredient. The model also predicts that rates higher than 215.7 L/ha would result in progressively sharper declines in yield. We consider this predicted yield decline plausible since metam-sodium is highly phytotoxic (1) and there would probably not be sufficient time in the 1-2 weeks elapsed from application to planting times to allow for decomposition and dissipation of high rates of the chemical. The concept of a "maximal recoverable yield" from nematicide applications agrees well with what has been observed for other nematicides in peanut (17). *Meloidogyne arenaria* juvenile populations in 1986 were considerably smaller than those in the previous year; 1986 was a dry year with irregular distribution of rains so that even though the field was irrigated almost continuously through the dry period (June-August), we were unable to maintain soil moisture at levels that we consider optimal for root system and *M. arenaria* population development. Yield response to Busan 1020 was proportionately sharper in 1986 than the year before. We interpret this difference as a reflection of the increased importance of root dam-

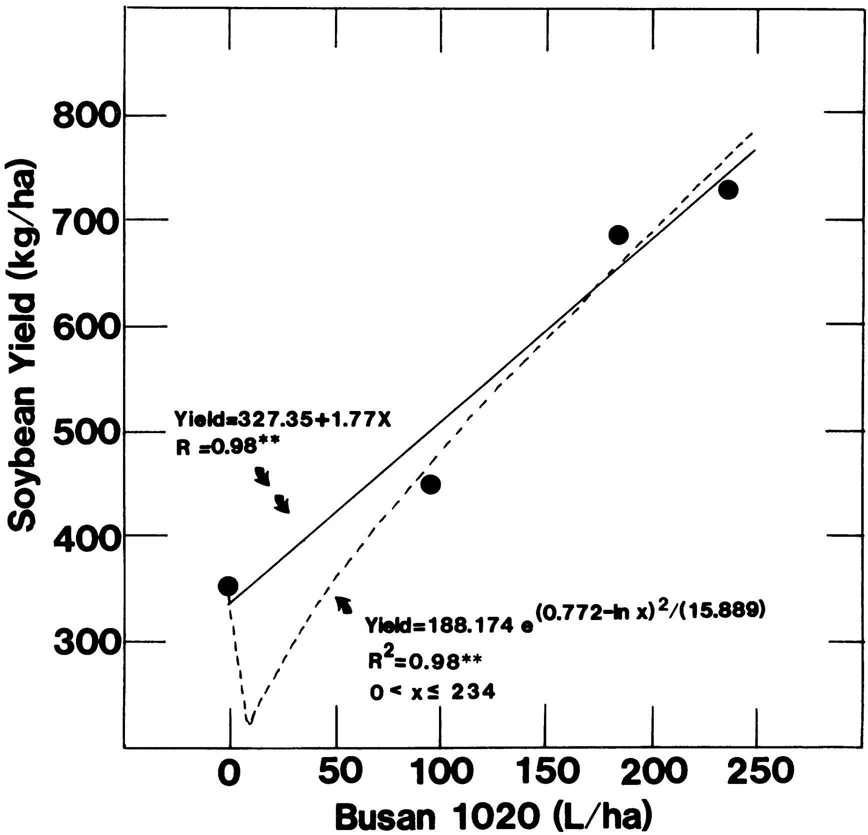

Fig. 3. Relation between soybean yields and pre-plant application rates of Busan 1020 (32.7% metam-sodium) in a 1985 experiment in a field infested with *M. incognita* and *H. glycines* near Elberta, Alabama.

age by nematodes in 1986; in a dry year yield loss per juvenile could be greater than in years with no water stress. We have demonstrated previously that the relation between yield and *M. arenaria* juveniles in soil is not constant and is influenced by the environmental conditions during the growing season (25). Unfortunately, numbers of juveniles were too low in 1986 to permit us to reliably establish their relation to yield. However, the 1985 data showed that yield response to Busan 1020 treatments was correlated to reductions in the size of juvenile populations in soil.

Data from the soybean experiment showed clearly that distinct positive yield responses to Busan 1020 can be obtained with preplant applications of the chemical at low rates. The 'Ransom' cultivar used in the experiment is susceptible to both *M. incognita* and *H. glycines,* hence the

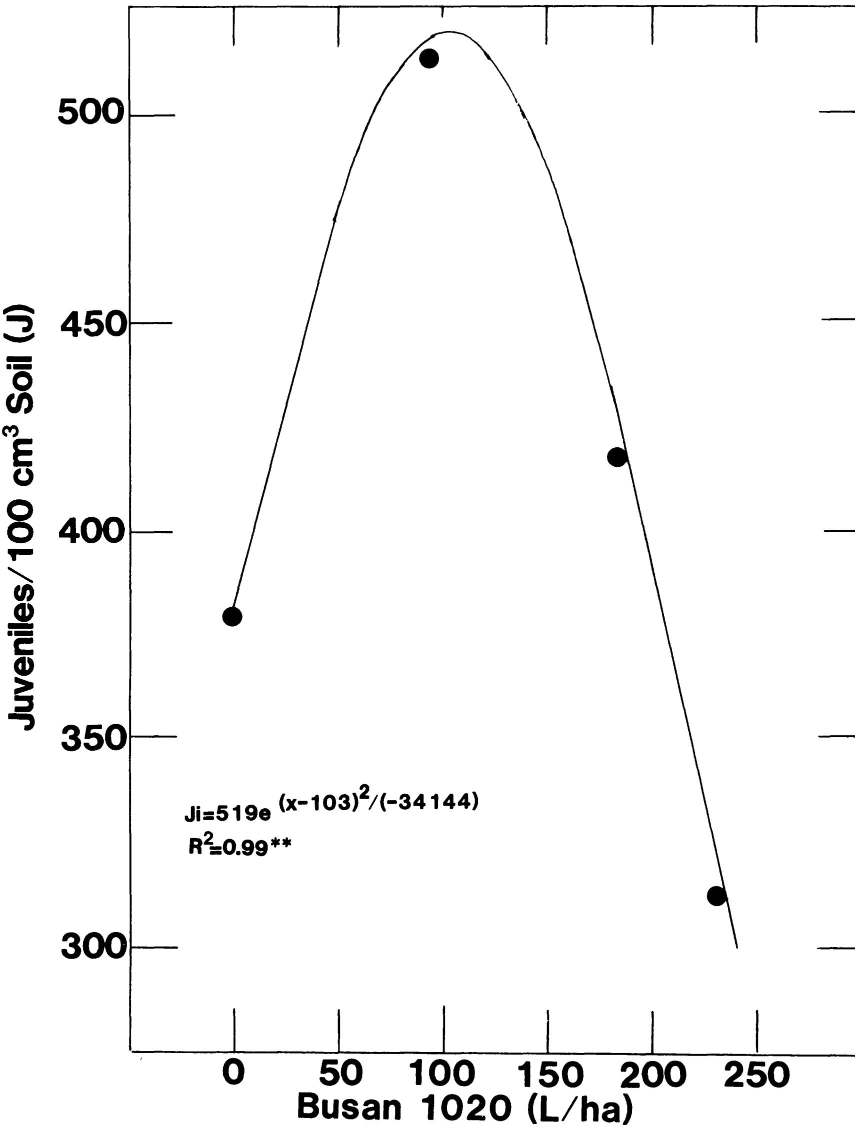

Fig. 4. Response of *M. incognita* juvenile populations to pre-plant application rates of Busan 1020 (32.7% metam-sodium) in a 1985 experiment with 'Ransom' soybean in a field near Elberta, Alabama.

very depressed yields in the experiment. Economic analysis of the yield data showed that none of the Busan 1020 treatments was profitable. It is possible that economical yield response could be obtained if Busan 1020 were used with cultivars tolerant to the nematodes as has been shown for other nematicides (8,9,20,22,30). The results suggest that the use of metam-sodium in soybeans without a nematode tolerant cultivar may not be economically feasible. Metam-sodium thus contrasts with other fumigants such as EDB or DBCP that were shown capable of delivering economical yield responses with nematode-susceptible soybean cultivars in fields with similar infestations as that in our experirent (20,22,30).

Soybean yield response to Busan 1020 was linearly related to application rates; however, other mathematical models provided also good descriptions of the relation. Fig. 3 presents a "log-normal" distribution model (broken line) that allows for loss of yield in response to low rates of application. We believe that in the field a loss of yield should correspond to increased numbers of *M. incognita* juveniles in a crop like soybean. The soybean growing period in south Alabama (May-Nov.) is longer than that of peanut (May-Sept.), a fact that is reflected in distinctly different patterns of population development of root-knot nematode juvenile in soil. Juvenile populations of *M. arenaria* in peanut follow an exponential growth model (24) in which numbers of juveniles are greatest at harvest time. It is thus possible that in peanut in contrast to soybean, stimulation of juvenile populations by nematicide applications may not result in yield declines since the crop is harvested early. In soybean, *M. incognita* juvenile population development follows a logistical model and reaches maximal numbers 6-8 weeks before harvest (22), hence there is ample time prior to harvest for nematode damage to result in yield reductions.

In conclusion, our results show that preplant applications of Busan 1020 in the range of 150-200 L/ha can profitably increase peanut yields when applied in-the-row 1-2 weeks prior to planting. The use of Busan 1020 with susceptible soybean cultivars may not be justified.

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