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韓應昆誌 27(1) : 35—40 (1988)
Korean J. Appl. Entomol.

Evaluation of Two Nematicides in the Initial Population Changes of the Soybean Cyst Nematode*

콩시스트線虫의 初期密度 變化에 있어서 두 가지 殺線虫劑의 効果檢定

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ABSTRACT The control efficiency of the nematicides, aldicarb and carbofuran, in the population dynamics of the soybean cyst nematode(*Heterodera glycines*) was evaluated. Nematode viability, penetration and reproduction were examined in greenhouse experiments. Nematode viability(movement) was greatly reduced by aldicarb, but not by carbofuran. Penetration was inhibited by both chemicals. Percentages of penetration relative to the untreated check 3 days after treatment were 0.4% and 1.7% for aldicarb and carbofuran, respectively. Systemic effects of the nematicides were observed with both nematicides but the effect was greater with aldicarb than with carbofuran. The total effect of the nematicides, applied at the time of planting soybean in infested soil, appeared to be less than the sum of the contact and systemic effects on the initial population dynamics of *H. glycines*.

KEY WORDS soybean cyst nematode, nematicides, chemical control

抄　錄 Aldicarb와 carbofuran 두 가지 殺線虫劑의 콩시스트 線虫初期密度 變化에 미치는 영향을 檢定하기 위하여 各藥劑의 線虫의 生存, 侵入 및 生殖에 對한 効果를 溫室實驗을 통하여 調査하였다. Aldicarb은 線虫의 生存(活力)에 미치는 영향이 컸으나 carbofuran은 線虫의 活力에 効果가 없었다. 線虫의 侵入沮止効果는 두 藥劑 모두 우수하였다. 藥劑處理에 의한 線虫의 侵入率은 對照區에 비해 aldicarb의 경우는 0.4%, carbofuran의 경우는 1.7%였다. 線虫侵入後 콩뿌리내의 線虫生長에 미치는 영향, 즉 殺線虫劑의 侵透性効果는 두 藥劑 모두에서 有意性이 認定되었고, aldicarb이 carbofuran보다 그 効果가 더 큰 것으로 나타났다. 線虫에 오염된 土壤에 유묘이식시 殺線虫劑를 處理한 結果, 各藥劑 處理區에서 cyst 형성율은 저하되었으나(p=0.05), 線虫의 生存, 侵入 및 生殖에 미치는 殺線虫劑 영향의 合計보다는 낮은 것으로 나타났다.

檢 索 語 콩시스트선충, 殺線虫劑, 化學的 防除

Soybean cyst nematode, *Heterodera glycines* Ichinohe, is an important pest on soybean. The major control measures are the use of resistant soybean cultivars, rotations and application of nematicides such as aldicarb and carbofuran. Nematicide effectiveness is usually evaluated by changes in nematode populations and/or plant growth and yield.

Nonfumigant nematicides such as aldicarb and carbofuran are organocarbamates. They are systemic nematicides which are applied in the soil to control endoparasitic nematodes on various crops (Dianzo 1981, Hough & Thomason 1975, Miller 1966, Schmitt 1985, Whitehead 1973). Their modes of action include reversible biniding of acetylcholinesterase, esterase inhibition and other pharmacological actions (Noel & Mayasich 1987, Spurr 1985).

The nematicides are usually applied before

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* Published with the approval of the Director of the Arkansas Agricultural Experiment Station. Supported in part by a grant from the Soybean Promotion Board.

or during planting for convenience. They decrease the initial nematode populations, which often governs the relative control efficiency.

The changes in the initial nematode population are due to the effects of the nematicide on nematode orientation, movement, penetration, feeding and reproduction. The nematicides have both contact and systemic actions which are associated with initial changes of nematode populations and protection of plants from nematode infection during early plant growth (Bunt 1987).

The purpose of this experiment was to evaluate nematicidal effects on population changes of the soybean cyst nematode and give basic information on the control of the nematode by nonvolatile nematicides.

MATERIALS AND METHODS

Cysts of *Heterodera glycines* (Hg) (a mixture of races 3 and 4) were soaked in water for 1 month and were mixed with sterile fine sand. The infested sand was evenly divided into 40×60×7 (cm) metal trays. Soybean(*Glycine max*(L.) Merr.) plants(cv. 'Lee') susceptible to all races of Hg were germinated in vermiculite and transplanted at the true leaf stage into the treated sand. Nematicides were applied at rates comparable to field application rates (aldicarb at 1. 1kg a.i./ha and carbofuran at 2. 2kg a.i./ha). They were mixed with the infested or sterile sand. Contact and systemic effects of the nematicides on the population dynamics of Hg were determined (Bunt 1987).

To test their effect as contact nematicides, they were applied at planting in the infested sand and the effects on nematode movement and penetration into the root systems were observed. To examine nematode viability in soil, the second stage juveniles (J_2) of Hg were extracted 3 days after treatment, using the Baermann funnel method, and the numbers of nematodes were counted. Also 6 soybean roots from each treatment were extracted 3 days after treatment and examined to determine the effect of the nematicides on nematode penetration.

The soybean roots were fixed in FPA (5% formalin and 5% propionic acid in 50% ethanol) for 1 day, bleached in 2% NaOCl for 10 min, and stained with 0. 07% bromophenol blue for 8 hours. The stained roots were rinsed with 50% ethanol, and Hg J_2 in the root system were counted.

Systemic effects of the nematicides were checked from two aspects, direct and residual effects. To study the direct systemic effects, soybean seedlings (cv. 'Lee') were inoculated as above and three days after planting they were transplanted into the fresh sand which was treated with each nematicide. Mature females and cysts were collected from sand and plants 33 days later by screening with a 60-mesh sieve, and counted.

To examine residual systemic effects of the nematicides on Hg, soybean plants (cv. 'Lee') were grown in nematicide-treated, nematode-free sand for 3 days. The plant roots were rinsed free of sand with tap water and transplanted to sterilized sand in 10×10cm (diameter×height) pots. About 300 J_2 of Hg race 3 were added to each plant. After 33 days, females were counted.

For comparison, soybean plantst (cv. 'Lee') were transplanted into the infested sand which also was treated with nematicides during planting. The cysts formed were screened on the 60-mesh sieve 33 days after planting and the number of mature females was counted.

RESULTS AND DISCUSSION

The viability of Hg J_2 was greatly reduced by aldicarb 3 days after treatment, while as many active Hg J_2 were recovered from carbofuran-treated sand as from the untreated check (Table 1). The percentage of active nematodes in treated sand compared to the control was 1.8% and 108.0% for aldicarb and carbofuran, respectively. However, the number of nematodes penetrating was greatly inhibited by both chemical treatments with penetration rates less than 2% of the number in the untreated check. The inhibition of penetration by aldicarb may be due to inhibition of hatching and/or nematode movement. The inhibition of nematode penetration by carbofuran, which was not significantly different from that in the aldicarb, did not appear to be due to a nemastatic effect as in aldicarb. Carbofuran may have caused a disfunction of the stylet muscle control, and as a result the nematodes were not able to penetrate the roots (Bunt 1987). Another possibility is that it disoriented the J_2 so they were not able to find the roots.

Both nematicides had systemic activity (Table 2). Infected plants planted in nema-

Table 1. Contact effects of nematicides on viability and penetration of the soybean cyst nematode

Nematicide	Number of juveniles	
	Viable in soil[a]	In plants[b]
None	1,661 ± 600(100.0)	1,233 ± 561(100.0)[c]
Aldicarb	30 ± 27(1.8)**[d]	5 ± 7(0.4)**
Carbofuran	1,794 ± 650(108.0)[NS]	21 ± 21(1.7)**
L S D(p=0.05)	398	619
(p=0.01)	551	859

[a] Treated sand was screened on a 400-mesh sieve and the nematodes were extracted by the Baermann funnel method (number of J_2/50ml soil).
[b] Number of juveniles in a root system stained with 0.07% bromophenol blue 3 days after inoculation.
[c] Averages±standard deviations of 6 replicates. The numbers in parentheses are percentages of the control.
[d] **=significant at p=0.01 and NS=not significant as measured by least significant difference (LSD).

Table 2. Direct systemic, residual systemic and total(contact and systemic) effects of nematicides on soybean cyst nematode female maturation[a]

Nematicide	No. females/plant		
	Direct systemic	Residual systemic	Total effect
None	315 ± 245(100)[b]	43 ± 24(100)	130 ± 24(100)
Aldicarb	10 ± 7(2.9)**[c]	7 ± 3(16.3)**	49 ± 16(37.7)*
Carbofuran	125 ± 57(37.2)*	14 ± 3(32.5)**	61 ± 18(46.0)*
L S D(p=0.05)	179	17	53
(p=0.01)	247	24	73

[a] For direct systemic effects, infected plants were planted in fresh sand with or without nematicide treatement, for residual systemic effects, nematicide-treated plants were planted in fresh sand, followed by inoculation with *Heterodera glycines*, and for total effects, nematicides were applied in the infested sand when seedlings were planted.
[b] Averages±standard deviations of 6 replicates. The numbers in parentheses are percentages of the control.
[c] *and**=significant difference at p=0.05 and p=0.01 from the control, respectively, as determined by least significant difference test (LSD).

ticide-treated sand had significantly fewer mature females on both aldicarb (p=0.01) and carbofuran (p=0.05) treated plants. Aldicarb-and carbofuran-treated plants transplanted into Hg-infested sand had significantly (p=0.01) fewer mature females than the untreated check (Table 2). The number of mature females relative to the control was 2.2% for aldicarb and 37.7% for carbofuran in the direct systemic effect, and 16.3% for aldicarb and 32.5% for carbofuran in the residual systemic effect.

The direct systemic effect may be due to inhibition of nematode feeding and reproduction, whereas the residual effect may be due to inhibition of nematode penetration and/or feeding and/or reproduction. The relative importance of the specific components in the systemic effect was not examined in this experiment; however, the nematicides were absorbed into the root systems and inhibited maturation of Hg.

When the nematicides were incorporated into sand heavily infested with Hg (to test the total effect of the nematicides), Hg maturation was significantly reduced by both (Table 2). Numbers of females recovered 33 days after inoculation were 37.7%

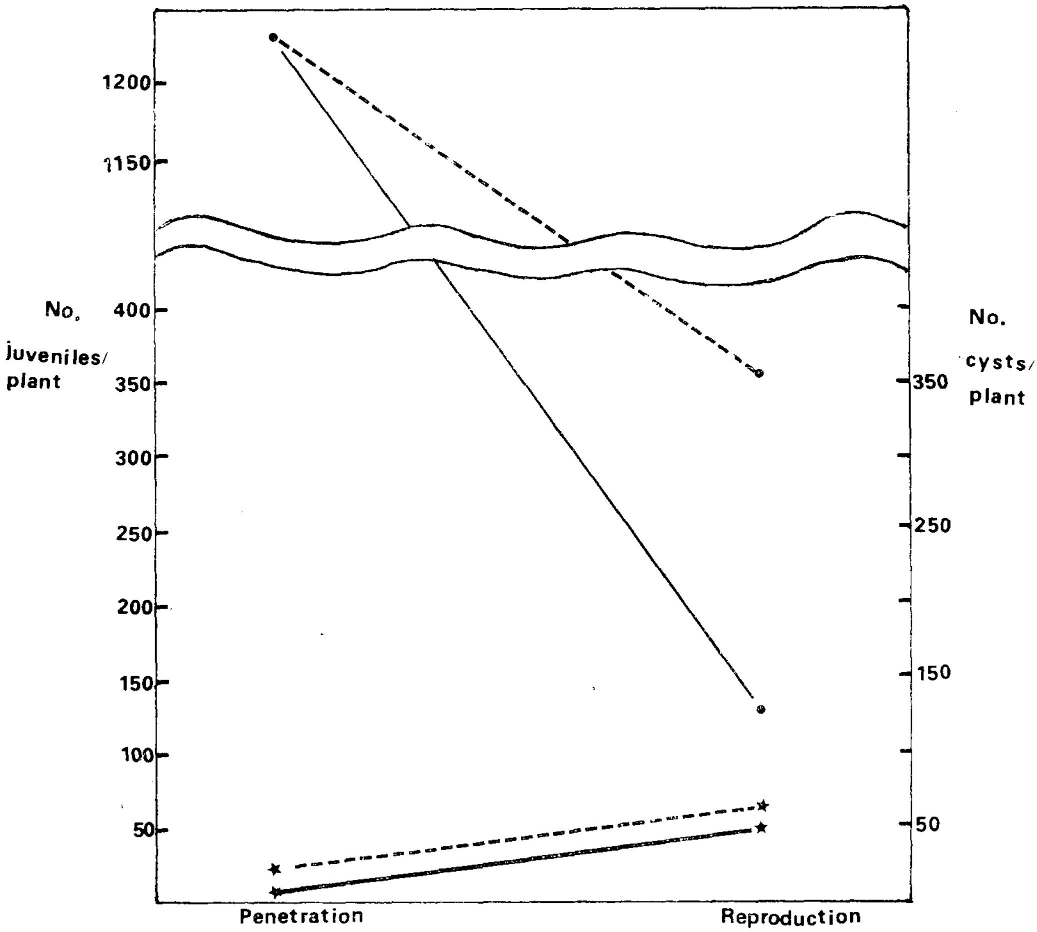

Fig. 1. Penetration(3 days after planting) and reproduction(33 days after inoculation) of the soybean cyst nematode in untreated check with additional nematode penetration(• —— •) and without additional nematode penetration, (• ······ •) and in aldicarb treatment (★——★) and carbofuran treatment (★······★) with additional nematode penetration.

in aldicarb-treated sand and 46.9% in carbofuran-treated sand compared to the untreated check. Both contact and systemic effects were obtained since the nematodes were exposed to the chemicals during the entire life cycle in the sand and inside the plant root.

The soybean plants in the total and direct systemic effect tests, were exposed to similar Hg populations. The number of juveniles in the roots of check plants after planting were much greater than the number of females recovered. Of 1,233±561 juveniles that penetrated only 130±24 (10.5%) and 315±245 (28.5%) matured into females(Fig. 1). The relative reproduction rate was less when seedlings were placed in infested sand and left there than when they were transplanted after 3 days into fresh sand. The only difference in the conditions of the tests was that the roots on non-transplanted plants were exposed to additional nematode penetration. Kim et al. (1987) reported that the percentage of Hg J_2 developing to mature females decreased in a high inoculum level. The reason for this was probably deterioration of root tissues by high numbers of J_2 penetrating. In the present study, additional nematode penetration probably inhibited the development of some females.

The number of Hg females recovered from nematicide-treated sand was greater than the number of juveniles in the roots 3 days after inoculation (Fig. 1). The relative increase was 9.8X and 2.9X for aldicarb and carbofuran, respectively.

After incorporation of the nematicides into sand, the concentration of the nematicide in the soil water decreases because of physical and biological processes (Bunt 1987). At nematicide concentrations below 1mg a.i./liter of soil, the root system is not protected against nematode infection. Root penetration and feeding increase (Bunt 1987). In some nematode species nematode activity may even be stimulated (Bostian, Schmitt & Baker 1984, Bunt 1975, Steele 1983). In addition, because of a lower nematode density in the root system the competition for feeding sites and root damage is less than with heavy infection (Kim, Riggs & Kim 1986). Therefore, the actual effect of the chemicals on the population dynamics of Hg does not appear to be as great as the sum of the contact and systemic effects of the nematicides, especially in the sand heavily infested with Hg. This may be due to density dependent population changes of Hg in the untreated soils and recovery of nematode activity in the treated soils infested with Hg allowing additional nematode infection. Plant growth and yield are not always correlated with Hg population changes (Bachireddy, Payne & Chin 1985, Baker et al. 1987, Muller, Noel & Sinclair 1982). The resurgence of nematode populations often occur and reach or even surpass the original population or the population in untreated fields (Bunt 1987). However, plant damage may be reduced by delaying nematode infection, allowing the plant to develop a healthy root system, thus it can tolerate more nematodes.

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(Received April 11, 1988)