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ECONOMICS & MARKETING

Improving Returns Using Nematicides in Cotton Fields Infested with Reniform Nematodes in Northwestern Florida

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INTERPRETIVE SUMMARY

Cotton is a major agronomic crop in the northern tier of counties of Florida. Reniform nematodes are found in 16% of all Florida cotton fields, mainly in the western panhandle region in northwest Florida. Management of this pest is by nematicides, crop rotation, or a combination of both practices. Rotation out of cotton is not an option for many growers because of the low prices of other agronomic crops, leaving nematicides as the only viable management option for growers who monoculture cotton. Current University of Florida nematicide recommendations are aldicarb and 1,3-D. The purpose of this study was to determine optimum application rates of the two nematicides on the basis of lint yield increase and partial net return.

Field experiments to determine lint yield increases and economic returns at four rates of 1,3-D and five rates of aldicarb were conducted over a 3-yr period at two separate northwest Florida locations. Crops were managed in accordance with best management practices published by the University of Florida Extension Program. Phorate was added to the 1,3-D tests and non-treated check at a rate of 0.67 kg a.i. ha^{-1} (kilogram active ingredient per hectare) to manage thrips. Aldicarb functions as a thrips-management agent as well as a nematicide. Cotton lint yields were numerically greater with all rates of both nematicides. The mean lint yield increases for all rates of 1,3-D was 24%. The mean lint yield increase for all rates of aldicarb was 13%. Mean lint yield increases for different rates of 1,3-D, while all yields greater than the non-treated check, were similar to each other, indicating that the smallest application rate was as effective as the largest rate. Mean lint yields of the different aldicarb rates were all numerically larger than the non-treated checks, but few were significantly greater - possibly indicating that the lowest application rate is as effective as the higher rates.

Economic benefits of the two nematicides were similar for their respective optimum application rates when compared with their non-treated checks. The lowest 1,3-D application rate of 16 kg a.i. ha^{-1} had the greatest increase in net return (\$90 ha^{-1}). Net returns declined at greater application rates because of increased costs of 1,3-D. Net returns at the different aldicarb rates reached a maximum of \$83 ha^{-1} for the 0.84 kg a.i. ha^{-1} rate and then declined because of the increased cost of aldicarb. The cost of a thrips-management agent, in this case phorate, must be added to the cost of 1,3-D when comparing costs and returns of 1,3-D to aldicarb. This additional cost reduces the partial net return for 1,3-D at the 16 kg a.i. ha^{-1} application from \$90 to \$72 ha^{-1}.

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ABSTRACT

The reniform nematode (*Rotylenchulus reniformis*) is a pest of cotton (*Gossypium hirsutum* L.), occurring in 16% of all cotton fields in Florida. Management is by crop rotation, the use of nematicides, or a combination of both practices. Crop rotation is not an option for many growers because of the relatively low prices of other agronomic crops, leaving nematicides as the only viable pest-management option. The objective of this research was to determine the optimum application rate of each of the two nematicides (1,3-D and aldicarb) recommended for use in Florida's cotton with respect to lint yield increase and economic return associated with the use of nematicides to improve lint yields (partial net return). Lint yields and partial net returns were evaluated on cotton grown in reniform nematode-infested loamy sand soils in northwestern

Florida. Four separate test sites were selected. Varying application rates of the nematicides were tested at each site and compared with a non-treated check over a 3-yr period. Lint yields and partial net returns increased using either nematicide. Because of significantly higher chemical and application costs of 1,3-D, use of 1,3-D resulted in greater lint yield increases compared with aldicarb, but aldicarb yielded greater partial net returns when both chemicals were applied at their respective optimum rates. These data suggest growers need to evaluate nematicides for improving partial net returns and increasing lint yield.

Upland cotton (*Gossypium hirsutum* L.) is a major agronomic crop in the northern tier of counties in Florida and was harvested on more than 37,000 ha in 2000 (USDA-FASS, 2001). Reniform nematodes (*Rotylenchulus reniformis* Linford & Oliveira) are found in 16% of Florida cotton fields, mainly in the heavier soils in the northwest region (Kinloch and Sprenkel, 1994). Management is by nematicides, rotation, or combinations of the two practices (Dunn and Noling, 1997).

Reniform nematode resistance is not available in commercial varieties. Rotation with other agronomic crops is not an option for many growers because of the relatively low prices of other agronomic crops. Nematicides are the only viable nematode management option for growers who grow cotton in monoculture.

The two nematicides used and recommended in Florida are aldicarb {2-methyl-2-(methylthio) propanal *O*-[(methylamino)carbonyl] oxime} and 1,3-D (1,3-dichloropropene) (Kinloch and Rich, 2000). Nematicide recommendations for reniform nematode management in Florida's cotton include 10- to 15-cm banded applications of aldicarb at 1.18 kg a.i ha^{-1}or single chisel row applications of 1,3-D at 32 kg a.i. ha^{-1}. These recommendations are based solely upon improvement in cotton yield in reniform nematode-infested fields.

Data concerning economic return due to their use are lacking. This study was conducted to determine economic return on investment for growers at several rates of 1,3-D and aldicarb. Incremental costs per kilogram of increased lint yield due to nematicide addition, net returns per kilogram of increased lint yield, and partial net returns per hectare were calculated for the different treatments (Boehlje and Eidman, 1984). The optimum treatment rate, based on partial net return per hectare, was calculated for each nematicide.

MATERIALS AND METHODS

A 3-yr nematicide study (Kinloch and Rich, 2000) involving four separate test sites infested with *R. reniformis* was conducted on a loamy, siliceous, thermic Grossarenic Paleudults soil of northwest Florida (USDA-NRCS, 2001). These test sites were typical of soils used in this cotton-production region. Three of the sites were in Gadsden County with the fourth site in Santa Rosa County. Soil at the Gadsden sites was a loamy sand (80% sand, 8% silt, 12% clay). Soil at the Santa Rosa site was also a loamy sand (82% sand, 10% silt, 8% clay). Two of the tests were conducted in Gadsden and Santa Rosa Counties in 1995. The other two tests were conducted in Gadsden County in 1997 and 1998.

Four rates of 1,3-D and five rates of aldicarb were used in these tests. Each treatment was replicated six times in the two 1995 tests and five times in the 1997 and 1998 tests. The trials included replicated non-treated check plots. Nematicide treatments were applied to plots two rows wide and 7.6 m long on 91-cm-wide centers. The fumigant 1,3-D was applied 30 cm deep with a single chisel beneath the row at rates of 16, 32, 48, and 64 kg a.i. ha^{-1} 14 to 17 d prior to planting. Phorate {*O*,*O*-diethyl *S*-[(ethylthio)methyl] phosphorodithioate} was added to the 1,3-D tests and the non-treated checks at a rate of 0.67 kg a.i. ha^{-1} to manage thrips [*Frankliniella occidentalis* (Pergande) and *F. fusca* (Hinds)]. It was assumed there was no additional application cost for phorate other than the chemical cost because it was applied at planting time. Granular aldicarb was applied in a 15-cm-wide band and incorporated at planting at rates of 0.50, 1.18, 1.51, and 2.02 kg a.i. ha^{-1} in the 1995 tests and 0.50, 0.84, 1.18, and 1.51 kg a.i. ha^{-1} in the 1997 and 1998 tests. Since aldicarb is also recommended for management of thrips, no additional thrips management was required for the aldicarb tests.

'Chembrand 407' cotton was planted in both 1995 tests. The planting dates for the Gadsden County and the Santa Rosa County sites were 8 May and 15 May, respectively. 'Delta Pine 5415 RR' cotton was used for the 1997 and 1998 tests.

Planting dates were 6 May for the 1997 test and 15 May for the 1998 test. Harvest dates were 15 December, 14 November, 3 December, and 16 October in the respective 1995, 1997, and 1998 tests. Soil fertility and weed and insect management at all sites were in accordance with standard practices (Sprenkel, 1995), and plots were irrigated as needed at the three Gadsden County sites. Entire plots were harvested for seed cotton yield and converted to lint yield by multiplying by 0.40. Lint yield increases, costs, and returns for each application rate are based on the average of all replicates of all tests. Individual plot data on lint yields, nematode population, and test methods have been reported previously (Rich and Kinloch, 2000).

The cost per kilogram of incremental lint yield was a major criterion for evaluating efficacy of treatment. Incremental lint yield is defined as the cost of producing additional lint yield over the non-treated check divided by the additional yield. For 1,3-D and aldicarb treatments, the cost per kilogram of incremental lint yield is equal to the nematicide price multiplied by the treatment rate of the nematicide plus the cost per application divided by the lint yield increase. A cost of \$18.23 ha^{-1} was used for the phorate treatment. Because phorate was added to the non-treated check, it was not considered as an incremental cost when comparing 1,3-D incremental costs only. Phorate costs were considered to be additional when 1,3-D and aldicarb were compared for cost effectiveness because aldicarb requires no additional thrips-management agent. Net return per kilogram increase is the price per kilogram increase (\$1.32 kg^{-1} for purposes of this analysis) minus the cost per kilogram of incremental lint yield. Partial net return is the additional return from incremental lint yield due to the treatment effect. It is defined as the net return per kilogram increase in lint yield multiplied by the lint yield increase associated with a given application rate. All partial net returns are expressed on a per-hectare basis.

RESULTS AND DISCUSSION

1,3-D Rates

Cotton mean lint yield was significantly increased (P £ 0.05) in three of the four tests relative to the non-treated check in which 1,3-D was applied (Kinloch and Rich, 2000). The lint yields from the 1995 Gadsden test were not found to be significantly greater than the non-treated check, although the lint yields for all treatment rates were numerically greater. No significant yield differences were found among the rates. The average lint yield increase for all application rates of 1,3-D was 126 kg ha^{-1} or 24%.

Cost per kilogram increase in lint yield, net return per kilogram increase in lint yield, and partial net return were calculated for each treatment

Table 1. Increases in lint yield per hectare, cost per kilogram, net return per kilogram, and partial net return per hectare of cotton grown in *Rotylenchulus reniformis*-infested soil treated with 1,3-D.

1,3-D treatment	Lint yield increase	Cost increase	Cost per kilogram increase	Net return increase	Partial net return
kg a.i. ha^{-1}	kg ha^{-1} †	\$ ha^{-1} ‡§¶	\$ #	\$ ††	\$ ha^{-1} ‡‡
0	0	-	-	-	-
16	112	58.26	0.520	0.800	89.58
32	134	110.74	0.826	0.494	66.14
48	120	163.22	1.360	-0.040	-4.82
64	139	215.70	1.552	-0.232	-32.22

† Lint yield increase = the average of all tests for a given treatment minus the mean of the non-treated checks.

‡ 1,3-D cost per kilogram = \$3.28.

§ 1,3-D is applied 14-17 d prior to planting at an application cost of \$5.78 ha^{-1}.

¶ 1,3-D cost increase = 1,3-D cost × 1,3-D treatment rate + 1,3-D application cost. (Phorate was not considered part of the 1,3-D cost increase since it was added to the non-treated check as well as to each treatment.)

\# Cost per kilogram increase = 1,3-D cost increase/lint yield increase.

†† Net return per kilogram increase (\$) relative to the non-treated check = \$1.32 minus cost per kilogram increase (assumes a cotton price of \$1.32 kg^{-1}).

‡‡ Partial net return = net return per kilogram increase × lint yield increase.

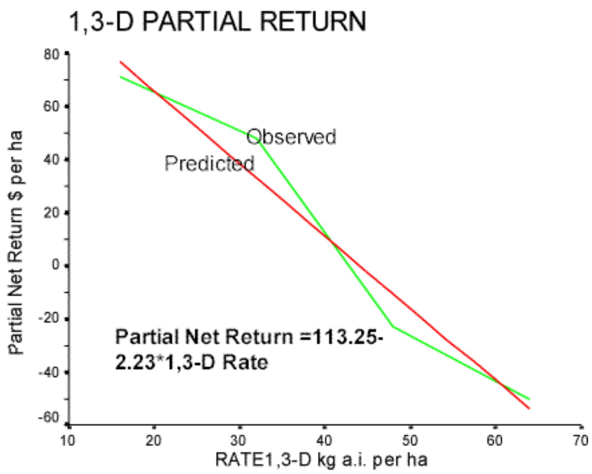

Fig. 1. Partial net return per hectare at different application rates of 1,3-D. The chart contains the observed partial returns versus rates of addition, as well as a linear fit of the observed results.

(Table 1). Partial net returns were positive for the 16 and 32 kg a.i. ha^{-1} application rates of 1,3-D, with the 16 kg a.i. ha^{-1} rate having the greatest partial net return ($89.58). That increase is consistent with the results showing lint yield increases for each application rate being greater than the non-treated check, but not differing significantly from each other. It is unclear whether a lower application rate would give the same lint yield increase response as the 16 kg a.i. ha^{-1} application rate. If that were true, the optimum application rate for maximum partial net returns would be less than 16 kg a.i. ha^{-1}. The best fit of partial net returns versus application rate was linear (Fig. 1), thus the optimum application rate for maximum partial net return was the lowest rate applied.

Aldicarb Rates

Kinloch and Rich's (2000) results for the four separate sites indicated that all five aldicarb treatment rates in the 1995 Santa Rosa County test had significantly greater lint yields than the non-treated check. Lint yields were not significantly different from the non-treated check for any treatment rate of aldicarb in the 1995 Gadsden County test. Lint yields were greater for the 0.84 kg a.i. ha^{-1} treatment than the non-treated check in the 1998 Gadsden test. All of the other treatments in the 1998 Gadsden test were not significantly different from the non-treated check. Average lint yield over all treatments increased 71 kg ha^{-1}or 13.3% of the non-treated check.

Partial net returns were positive for all rates except for the 2.02 kg a.i ha^{-1} rate (Table 2). The greatest partial return ($82.81) was achieved using the 0.84 kg a.i. ha^{-1} application rate. A quadratic model (SPSS, 1998) of partial net returns versus application rate (Fig. 2) gave the best-fitted curve. The optimum application rate was identified by differentiating the quadratic equation shown in Fig. 2 (Allen, 1938), setting the derivative equal to zero, and then solving for the aldicarb rate that gave the maximum partial net return. Differentiation of the second-order curve gave an estimated rate of 1.04 kg a.i. ha^{-1} for the maximum partial net return.

Table 2. Increases in lint yield per hectare, cost per kilogram, net return per kilogram, and partial net return per hectare of cotton grown in *Rotylenchulus reniformis*-infested soil treated with aldicarb.

Aldicarb treatment	Lint yield increase	Cost increase	Cost per kilogram increase	Net return increase	Partial net return
kg a.i. ha^{-1}	kg ha^{-1}†	$ ha^{-1}‡§¶	$ #	$ ††	$ ha^{-1}‡‡
0	-	-	-	-	-
0.5	45	22.05	0.49	0.83	37.35
0.84	91	37.31	0.41	0.91	82.81
1.18	94	51.70	0.55	0.77	72.38
1.51	80	66.40	0.83	0.49	39.20
2.02	57	88.92	1.56	-0.24	-13.68

† Lint yield increase = the average of all tests for a given treatment minus the mean of the non-treated checks.
‡ Aldicarb cost per kilogram a.i. = $44.00.
§ Aldicarb application cost is negligible because of addition at planting.
¶ Aldicarb cost increase = cost of aldicarb × aldicarb rate.
# Cost per kilogram increase ($) relative to the non-treated check = aldicarb cost increase/lint yield increase.
†† Net return per kilogram increase = $1.32 minus cost per kilogram increase (assumes cotton price of $1.32 kg^{-1}).
‡‡ Partial net return = net return per kilogram increase × lint yield increase.

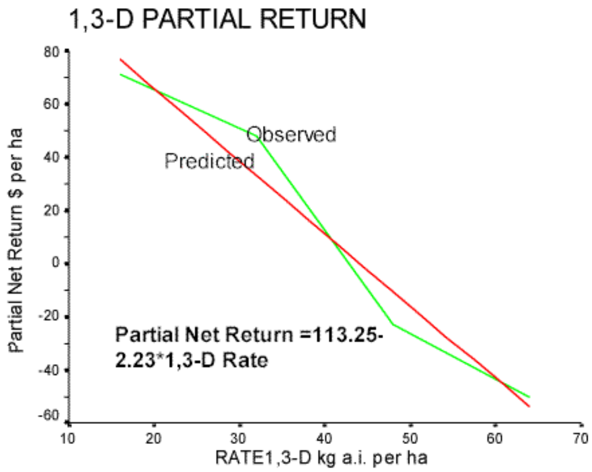

Fig. 1. Partial net return per hectare at different application rates of 1,3-D. The chart contains the observed partial returns versus rates of addition, as well as a linear fit of the observed results.

Comparison of Partial Net Returns

The additional benefit of thrips management associated with aldicarb must be taken into account in order to compare costs and returns on an equivalent basis. The per-hectare cost of phorate ($18.23) to manage thrips is added to the cost of 1,3-D in Table 3. Costs and returns of 1,3-D rates in the table reflect the additional cost of phorate used to place the two nematicides on an equivalent benefit basis.

A comparison of partial net returns for 1,3-D and aldicarb is shown in tabular form in Table 3. Aldicarb has a higher partial net return ($83 versus $71 ha^{-1}) at optimum application rates because of the additional $18 ha^{-1} cost of phorate for thrips management. While 1,3-D incremental lint yields are substantially greater than aldicarb lint yields (Rich and Kinloch, 2000), the greater application cost of 1,3-D plus phorate offsets its yield advantage. The use of a thrips-management agent less costly than phorate may improve the partial net returns of 1,3-D. Other factors such as nematicide availability, ease of application, or equipment availability may determine choice of nematicide.

CONCLUSIONS

The analysis indicates that the currently recommended rates (Kinloch and Rich, 2000) of both 1,3-D (32 kg a.i. ha^{-1}) and aldicarb (1.18 kg a.i. ha^{-1}) may be higher than desired for maximum economic return in Florida cotton fields infested with reniform nematodes. The data demonstrate a need to interpret results on the basis of economic returns in lieu of maximum agricultural output. Future trials should be conducted to determine whether a lower rate of 1,3-D would have a greater partial net return than the currently recommended 16 kg a.i. ha^{-1} rate.

Table 3. Comparison of partial net returns of cotton grown in a *Rotylenchulus reniformis*-infested soil treated with 1,3-D or aldicarb.

Nematicide	Application rate	Yield increase	Application cost increase	Revenue increase	Partial net return
	kg a.i. ha^{-1}	kg ha^{-1}	\$ ha^{-1} †‡§	\$ ha^{-1} ¶	\$ ha^{-1} #
1,3-D	0	-	-	-	-
1,3-D	16	112	76.49	147.84	71.35
1,3-D	32	134	128.97	176.88	47.91
1,3-D	48	120	181.45	158.40	-23.05
1,3-D	64	139	233.93	183.48	-50.45
Aldicarb	0	-	-	-	-
Aldicarb	0.5	45	22.00	59.40	37.40
Aldicarb	0.84	91	36.96	120.12	83.16
Aldicarb	1.18	94	51.92	124.08	72.16
Aldicarb	1.51	80	66.44	105.60	39.16
Aldicarb	2.02	57	88.88	75.24	-13.64

† The cost of phorate ($18.23 ha^{-1}) was added to 1,3-D application costs from Table 1 for thrips management in order to match aldicarb thrips-management benefits.

‡ 1,3-D cost increase = 1,3-D cost ($3.28) × 1,3-D treatment rate + 1,3-D application rate ($5.78) + phorate cost ($18.23).

§ Aldicarb cost increase = cost of aldicarb ($44.00 kg^{-1}) × aldicarb rate.

¶ Revenue increase = $1.32 kg^{-1} × lint yield increase.

Partial net return = revenue increase minus cost increase.

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