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A Gross Margin Comparison of Returns to Nematicide Treatment in Continuous and Rotation Triticale-Soybean Production

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A study of irrigated strip-till soybean production compared gross margins over nematicide expense for a continuous triticale-soybean system versus a two-year rotation system alternating triticale-soybean with triticale-cotton. Half of the replicated plots under each system received nematicide treatment. Gross margins were calculated using recorded yields and Georgia average market prices by marketing years. Mean gross margins for untreated plots were not significantly different between crop-sequence systems. Within each system, however, mean gross margins were significantly higher for plots not receiving nematicide treatment versus treated plots, even when treated plots produced greater yields.

Key Words: conservation tillage, gross margin, irrigation, *Meloidogyne incognita*, root-knot nematode, rotation, soybean, triticale

Soybean crops are especially susceptible to attack by many nematode genera (Schmitt and Noel, 1984). In the Georgia Coastal Plain, the nematodes causing economic damage to soybean include root-knot (*Meloidogyne* spp.), soybean cyst (*Heterodera glycines* Ichinohe), Columbia lance (*Hoplolaimus columbus* Sher), reniform (*Rotylenchulus reniformis* Linford and Oliveira), and sting (*Belonolaimus longicaudatus* Rau). Soybean losses to nematodes in Georgia were estimated at $3.75 million in 1995, representing more than half of the total disease losses for the crop and 6.5% of the 1995 total crop value (Bertrand, 1996).

Management of nematodes has been achieved through selection of resistant soybean cultivars, crop rotations, and use of nematicides (Boquet and Hutchinson, 1993; Dabney et al., 1988; Edwards, Thurlow, and Eason, 1988; Schmitt and Noel, 1984). Unfortunately, no regionally adapted soybean varieties exist with resistance to all

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nematodes. Cotton (*Gossypium hirsutum* L.), peanut (*Arachis hypogaea* L.), and tobacco (*Nicotiana tabacum* L.) are nonhost annual crops to specific nematode genera of agricultural importance currently grown in the Coastal Plain region (Padgett, 1995; Woodruff, 1996). Higher levels of nematode control are possible with nematicide treatments, but this option may lead to increased production costs. Economic feasibility of nematicide treatments has not been widely analyzed in the Coastal Plain for soybeans, especially in conjunction with doublecrop rotation systems.

The objective of this research was to determine the economic feasibility of a nematicide application under different small grain-soybean production systems. The null hypothesis was that application of a nematicide to doublecrop soybean systems would significantly increase net returns per acre. To test this hypothesis, comparisons of gross margins over nematicide expense were made between annual rotation doublecrop and continuous doublecrop soybean production systems.

Research Approach

An experiment on Tifton loamy sand (fine-loamy siliceous, thermic Plinthic Kandiudults) naturally infested with root-knot nematode [*Meloidogyne incognita* (Kofoid and White) Chitwood] under irrigation was used to establish a five-year study with: (*a*) a continuous doublecrop production system using triticale (X *Triticosecale* Whittmack) cv. Beagle 82/soybean [*Glycine max* (L.) Merr.] cv. Twiggs, and (*b*) a two-year rotation doublecrop production system using triticale-soybean and triticale-cotton (*Gossypium hirsutum* L.) cv. McNair 235 (table 1). Both soybean cv. Twiggs and cotton cv. McNair 235 are moderately resistant to *M. incognita*.[1] The host-parasite relationship between triticale cv. Beagle 82 and *M. incognita* has not been determined.

The experiment was conducted at the Coastal Plain Experiment Station, Tifton, Georgia. All plots were established and maintained under an integrated pest management conservation tillage program consisting of mechanical cotton stalk pulling with flail mowing, grain drill seeding of triticale in November, and row-till subsoil planting of cotton or soybean in June. Each field was split into a randomized complete-block design with half of the plots receiving two broadcast applications of nematicide (fenamiphos) by chemigation. The first application [6 lbs. active ingredient per acre (a.i./A)] was made immediately following the triticale seeding, and the second application (6 lbs. a.i./A) was made following row-till planting of soybean and cotton.

The land had previously been partitioned (1975–1980) under four pest management treatments—standard check (methyl bromide), maximum (all pesticides), optimum (monitoring), and minimum—and planted to *M. incognita*-susceptible

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[1] Personal communications with J. M. Woodruff and S. H. Baker, research agronomists, Department of Crop and Soil Sciences, The University of Georgia, Coastal Plain Experiment Station, Tifton, Georgia.

Table 1. Crop Sequences of the Two Production Systems

Production System	Years	Crop Sequences
Cropping System 1:	1987–1991	Continuous Annual Triticale-Soybean (triticale cv. Beagle 82, cotton cv. McNair 235, and soybean cv. Twiggs)
Cropping System 2:	1987	Triticale-Cotton
	1988	Triticale-Soybean
	1989	Triticale-Cotton
	1990	Triticale-Soybean
	1991	Triticale-Cotton

"Yellow Jewel" sweet potato [*Ipomoea batatas* (L.) Lam]. Beginning in 1981, the standard check and optimum treated areas were both designated as optimum management (with fenamiphos), and the maximum and minimum treated plots became minimum management (no fenamiphos). These designations were carried forward in 1987, when the continuous and rotation cropping sequence research was initiated and, though the nematode treatments were identical, separate yield data were recorded from each plot set. Burn-down herbicides for the row crops were applied by ground spray equipment. Most fertilizer and chemical applications were made through the chemigation system.

Twenty soil cores (1 inch diameter × 6 inches deep) for nematode assay were collected monthly from all plots each year. Soil samples from each plot were mixed thoroughly, and a 150-cm^3 subsample was processed by a centrifugal-flotation method (Jenkins, 1964). Numbers of *M. incognita* second-stage juveniles (J2) were recorded.

Theoretical Framework

The theoretical approach for this research study considers a profit function where net return to management (*NR*) is a function of gross returns and total cost. Gross returns are derived from vectors of outputs $\mathbf{Y}$ and market prices $\mathbf{P}_Y$. Total cost is derived from production input vectors of fixed $\mathbf{X}_F$ and variable $\mathbf{X}_V$ input quantities, and a corresponding vector of input prices $\mathbf{P}_X$. The functional relationship can be expressed as follows:

$$(1) \qquad NR = f\left[\mathbf{Y}, \mathbf{P}_Y, \mathbf{X}_F, \mathbf{X}_V, \mathbf{P}_X\right].$$

Multi-year extensions of this functional relationship can be developed by incorporating observations over time into the profit model. Net return to management for a given time period (t) is expressed as:

$$NR_t = (Y_t * P_{Y,t}) - \Big((x_{F,t}) * (P_{x_{F,t}}) - (x_{V,t}) * (P_{x_{V,t}})\Big), \quad t = 1, 2, \ldots, T, \tag{2}$$

where

NR_t = net return to management in period t,
Y_t = yield in period t,
$P_{Y,t}$ = soybean market price in period t,
$x_{F,t}$ = quantity of fixed input x in period t,
$x_{V,t}$ = quantity of variable input v in period t, and
P_x = price of fixed input $x_{F,t}$ or variable input $x_{V,t}$, respectively, in period t.

Empirical Framework

Testing of the null hypothesis was conducted through a partial budget economic analysis that calculated gross margin over nematicide expense. Gross margin per unit is commonly defined as the difference between total income and total variable cost (Kay and Edwards, 1994). For a farm operation to remain solvent over the long run, fixed costs must be fully covered by the total gross margin summed over all enterprises on the farm. Gross margin analysis is a commonly used approach in agricultural economics when examining small adjustments in production technologies. Our study departs from common definitions of gross margin by disregarding both the fixed costs *and* all commonly shared variable cost items. In this sense, the analysis embraces partial budgeting principles that have also long been utilized in production economics. For this research, gross margin over nematicide expense (GM_N) is defined as:

$$GM_N = (Y_s * P_s) + (Y_{tr} * P_{tr}) - (N_s) - (N_{tr}), \tag{3}$$

where

GM_N = system gross margin over nematicide expense,
Y_s = soybean yield per acre,
P_s = Georgia marketing year average soybean price,
Y_{tr} = triticale yield per acre,
P_{tr} = Georgia marketing year average triticale price (Georgia state corn average price was used as a proxy for the triticale price),
N_s = nematicide treatment expense on soybean, and
N_{tr} = nematicide treatment expense on triticale.

Yield, output price, and nematicide expense were entered into a custom-designed spreadsheet developed in Microsoft EXCEL (Microsoft Corp., 1992). Using this spreadsheet, gross margin calculations were made by crop sequence and treatment. Mean data results were analyzed by the SAS statistical analysis program (SAS Institute, Inc., 1985).

Data

Yield, price, and nematicide input data were used to generate the gross margins over nematicide expense for years with triticale-soybean production under both systems. Yield data represented triticale and soybean harvests taken by plot with a combine. Six replications of each cropping sequence-nematode management combination were obtained annually for each crop. As noted earlier, the four sets of replications could have been regarded as two sets on the basis of nematicide treatment. Two years of yield data were available for the triticale-soybean system under crop rotation. Therefore, comparisons with the continuous triticale-soybean system could only be made over two years of production.

Annual market prices for soybean were obtained from the Georgia Agricultural Statistics Service (1995). Fenamiphos price was obtained from a limited survey of south Georgia farm supply centers (Stark, 1995) and a national pesticide price list (DPRA, Inc., 1994).

Nematicide input data were taken from research report summaries of the U.S. Department of Agriculture/Agricultural Research Service (USDA/ARS) at the Coastal Plain Experiment Station (Sklany, 1988, 1990). The reports contain both the quantities of fenamiphos and dates of application for each year. No application charge was included since all nematicide treatments were made immediately following crop plantings and in conjunction with chemigation applications of preemergence herbicides.

Results

Analysis of the research results was conducted in two steps. First, triticale and soybean production yield comparisons were made between crop sequences and nematicide treatments. This step mirrors the initial comparisons that most producers make when choosing among production system combinations. Then a second set of comparisons was made on the basis of gross margins over nematicide expense. The results of this comparison set are most important since they directly affect the economic viability of the triticale-soybean enterprise combination and that portion of the farm operation.

Yield Comparisons

Triticale Yields

Mean yield per acre results for triticale may be analyzed on the basis of production system and nematicide treatment. Mean yield results indicated a significant advantage for the continuous triticale-soybean system over the two-year rotation system when observed over the entire data period (table 2). During 1988, a relatively wet production year, no significant yield differences were observed among any system-treatment combinations. In the drier production period, 1990, a significant yield advantage was found for the continuous system over the two-year rotation system.

Table 2. Triticale Yields (in bushels/acre) by Crop Sequence and Nematode Treatment

Year		Continuous with Nematicide	Continuous w/No Nematicide	Rotation with Nematicide	Rotation w/No Nematicide
1988		46.26	43.55	41.08	43.02
		42.34	45.92	43.31	43.60
	Mean Yield:	**44.30 (a)**	**44.73 (a)**	**42.20 (a)**	**43.31 (a)**
1990		40.99	39.78	32.82	27.99
		41.81	43.16	33.88	30.16
	Mean Yield:	**41.40 (a)**	**41.47 (a)**	**33.35 (b)**	**29.07 (c)**
Overall Mean Yield:		**42.85 (a)**	**43.10 (a)**	**37.77 (b)**	**36.19 (b)**

Note: Annual or overall means (bolded numbers) on the same row that are followed by the same letter are not significantly different at the 5% level.

Yield differences associated with nematicide treatments were found only in 1990. A significant yield advantage was found for rotation plots receiving nematicide treatments versus those without a treatment. The continuous triticale-soybean system showed no yield difference between nematicide treatments.

Soybean Yields

Soybean yields were also compared among production systems and nematicide treatments. Mean yields per acre were highest each year for the continuous triticale-soybean sequence with a nematicide treatment, and were significantly higher than all other combinations in 1988 (table 3). Second-highest yields in 1988 occurred on plots where row crop rotation was practiced, but a nematicide was not applied. When averaged over both years of the study, untreated continuous and untreated rotation plots both yielded significantly less than continuous cropping with a nematode treatment. But both sets of untreated plots yielded significantly more than rotation-cropped plots that received a nematicide treatment.

A yield increase with rotation occurred in 1988, when no nematicide treatment was applied. Mean soybean yield was more than 2 bushels per acre higher for rotation plots compared to the continuous triticale-soybean. A yield advantage from rotation was not observed during 1990 for treated or untreated plots.

Despite the use of irrigation, moisture level may have been a factor in the soybean yields. Yields under all cropping sequence-nematicide treatment combinations in 1990 were generally 70–80% of the 1988 yields. Rainfall in 1988 was much greater than in 1990. Crops received more than 53 inches of water in 1988 from natural rainfall and irrigation. During 1990, less than 38 inches of water were available over the doublecrop growing season.

Table 3. Soybean Yields (in bushels/acre) by Crop Sequence and Nematode Treatment

Year		Continuous with Nematicide	Continuous w/No Nematicide	Rotation with Nematicide	Rotation w/No Nematicide
1988		37.92	31.96	33.12	34.56
		34.32	29.52	23.20	31.00
	Mean Yield:	**36.12 (a)**	**30.74 (c)**	**28.16 (d)**	**32.78 (b)**
1990		27.27	22.62	24.54	22.12
		24.49	25.19	22.81	25.34
	Mean Yield:	**25.88 (a)**	**23.91 (a)**	**23.68 (a)**	**23.73 (a)**
Overall Mean Yield:		**31.00 (a)**	**27.32 (b)**	**25.92 (c)**	**28.26 (b)**

Note: Annual or overall means (bolded numbers) on the same row that are followed by the same letter are not significantly different at the 5% level.

Following susceptible "Yellow Jewel" sweet potato, numbers of *M. incognita* J2 declined on triticale and soybean, but increased on cotton. At planting of soybean and cotton each year, numbers of *M. incognita* J2 were below detection levels, increasing to 200 J2/150 cm^3 soil in continuous and 75 J2/150 cm^3 soil in rotation soybean plots in 1988, and 300–600 J2/150 cm^3 soil in both continuous and rotation soybean in 1990. The application of fenamiphos did not suppress *M. incognita* population densities (P = 0.05). Over three years, mean yields of triticale and soybean were 5.63% and 5.10% greater, respectively, from fenamiphos-treated plots compared to untreated plots.

Gross Margin Comparisons

Economic comparisons among production combinations were made on the basis of gross margin over nematicide expense (tables 4, 5, and 6). These comparisons may then be examined in greater detail from the perspectives of cropping sequence or nematicide treatment. Results of the comparisons contradicted the agronomic rankings by yield.

Triticale Gross Margins

Gross margin results from the triticale portion of this study show a significant advantage in favor of no nematicide treatment (table 4). In both years, untreated plots generated higher gross margins over nematicide expense regardless of the cropping sequence followed. Further significant advantages were observed in the drier year, 1990, for the continuous cropping sequence over the rotation sequence.

Table 4. Triticale Gross Margins (in $/acre) over Nematicide Expense by Crop Sequence and Nematode Treatment

Year	Continuous with Nematicide	Continuous w/No Nematicide	Rotation with Nematicide	Rotation w/No Nematicide
1988	−3.97	131.52	−19.59	129.91
	−15.79	138.67	−12.87	131.66
Mean Gross Margin:	**−9.88 (b)**	**135.09 (a)**	**−16.23 (b)**	**130.79 (a)**
1990	−30.13	110.19	−52.75	77.52
	−27.85	119.56	−49.81	83.54
Mean Gross Margin:	**−28.99 (c)**	**114.87 (a)**	**−51.28 (d)**	**80.53 (b)**
Overall Mean Gross Margin:	**−19.44 (c)**	**124.98 (a)**	**−33.76 (d)**	**105.66 (b)**

Note: Annual or overall means (bolded numbers) on the same row that are followed by the same letter are not significantly different at the 5% level.

Table 5. Soybean Gross Margins (in $/acre) over Nematicide Expense by Crop Sequence and Nematode Treatment

Year	Continuous with Nematicide	Continuous w/No Nematicide	Rotation with Nematicide	Rotation w/No Nematicide
1988	133.16	233.31	98.12	252.29
	106.88	215.50	25.70	226.30
Mean Gross Margin:	**120.02 (b)**	**224.40 (a)**	**61.91 (c)**	**239.29 (a)**
1990	12.88	129.86	−2.78	126.97
	−3.10	144.60	−12.74	145.47
Mean Gross Margin:	**4.89 (b)**	**137.23 (a)**	**−7.76 (b)**	**136.22 (a)**
Overall Mean Gross Margin:	**62.45 (b)**	**180.82 (a)**	**27.07 (c)**	**187.76 (a)**

Note: Annual or overall means (bolded numbers) on the same row that are followed by the same letter are not significantly different at the 5% level.

The significant gross margin differences of 1990 persisted when gross margins were calculated over the full two-year period.

Soybean Gross Margins

Highest soybean gross margins over nematicide expense per acre were always realized where no nematicide treatment was applied (table 5). Significant differences

Table 6. Triticale-Soybean System Gross Margins (in $/acre) over Nematicide Expense by Crop Sequence and Nematode Treatment

Year	Continuous with Nematicide	Continuous w/No Nematicide	Rotation with Nematicide	Rotation w/No Nematicide
1988	129.19	364.82	78.53	382.20
	91.08	354.16	12.83	357.96
Mean Gross Margin:	**110.13 (b)**	**359.49 (a)**	**45.68 (c)**	**370.08 (a)**
1990	−17.25	240.05	−55.53	204.49
	−30.95	264.16	−62.55	229.02
Mean Gross Margin:	**−24.10 (c)**	**252.10 (a)**	**−59.04 (d)**	**216.75 (b)**
Overall Mean Gross Margin:	**43.02 (b)**	**305.80 (a)**	**−6.68 (c)**	**293.42 (a)**

Note: Annual or overall means (bolded numbers) on the same row that are followed by the same letter are not significantly different at the 5% level.

in gross margin were found over all treated plots. The cropping sequence, continuous versus rotation, only produced a significant difference in 1988, where continuous triticale-soybean with a nematicide treatment had a higher gross margin than the rotated sequence. During the drier 1990, no significant difference due to cropping sequence was found regardless of the nematicide treatment employed.

System Gross Margins

Combining separate gross margin over nematicide expense results from the triticale and soybean enterprises provided system-level economic results for cropping sequences and nematicide treatments, respectively (table 6). Significant gross margin advantages were found for all plots not receiving a nematicide treatment. Where a nematicide was applied, gross margins were significantly higher for the continuous cropping sequence. Comparison of continuous versus rotation cropping sequences revealed essentially no significant differences in gross margin when no nematicide treatment was applied.

Conclusions

The major conclusions formed from the findings of this research experiment are based on the crop yield, crop gross margin over nematicide expense, system gross margin over nematicide expense results, and nematode population densities. Two conclusions address yield results, and the remaining conclusions arise from gross margin analysis and other factors.

First, producers who select a cropping sequence-nematicide treatment combination on the basis of triticale yield can maximize their yield by adopting a continuous triticale-soybean production system. Triticale yield will not be significantly affected by nematicide treatment choice, given the numbers of *M. incognita* reported in this study. This suggests that the yield benefits generally assumed to occur with crop rotations may not be realized on soils of the Georgia Coastal Plain when a nematicide treatment is applied concurrently.

Second, producers who select a cropping sequence-nematicide treatment combination on the basis of soybean yield would maximize yield by applying nematicide treatment under a continuous triticale-soybean system. If producers instead select a two-year rotation of triticale-soybean and triticale with a small grain-nonlegume row crop having moderate resistance to *M. incognita*, highest soybean yields would be expected without a nematicide treatment.

Third, producers who select either the continuous or rotation cropping sequence are almost always more likely to generate higher gross margins over nematicide expense when they forego a nematicide application. Gross margin advantages of \$250 to \$325 per acre were obtained from the untreated systems over the corresponding treated systems.

Fourth, producers who choose to not apply a nematicide can select either the continuous or the rotation cropping sequence with no significant system-level difference in expected gross margin over nematicide expense. This conclusion may hold only when producers select crop cultivars that are moderately resistant to *M. incognita*. While significantly higher mean triticale gross margins over nematicide expense would be expected under the continuous cropping sequence, soybean gross margins show no significant difference, thus leading to the total system results.

The conclusions reached from this study provide triticale-soybean doublecrop producers with information that may be used in developing crop production technologies. The combination of yield and gross margin over nematicide expense outcomes gives flexibility with regard to yield and gross margin maximization choices, and allows producers to select a cropping sequence and nematicide treatment option that most closely matches the overall goals and needs of their farm operation and potential nematode population densities present in the soil.

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