Profitability of Variable versus Uniform Rate Nematicide for Sugar Beets

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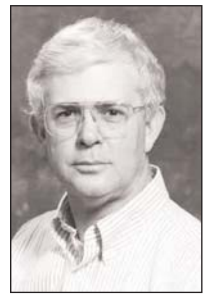
Abstract

The benefit of applying fumigant for control of the sugar beet nematode on a variable versus uniform rate basis is examined. Compared to fumigating an entire field at a uniform rate labeled for nematode suppression, variable rate application provides extra profit ranging from $4/acre (heavily infested field) to $69/acre (lightly infested field). In addition, adverse environmental impacts are minimized by reductions in product usage.



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Background

The sugar beet nematode (Heterodera schachtii) is a major root parasite of sugar beets. It causes severe stand and yield reductions wherever sugar beets are produced, particularly with fields located near refineries where they have been grown consistently for many years (Gray and Koch, 1997). Crop rotations are important for control of nematodes. However, rotations long enough to alleviate the need for nematicide (three to five years or longer out of beets) are not always practical in many areas due to the lack of profitable alternative crops. As a result, sugar beet growers have relied heavily on nematicide such as Telone II® (1,3-dichloropropene), a restricted use pesticide, to achieve control of nematodes. As of 1997, Telone II® was applied to an estimated 45,000 acres of sugar beets across Colorado, Idaho, Nebraska, and Wyoming (EPA, 2000).

Soil fumigation with Telone II® represents one of the largest expenses in sugar beet production, costing up to $150/acre for the product alone. Moreover, it can generate significant risks to applicators and the environment. Therefore, incentives are high to eliminate, or at least reduce nematicide usage from the standpoint of cost efficiency and environmental benefits. Yet, lower sugar beet production, as a result of eliminating or reducing nematicide, may negatively impact not only sugar beet producers and their earnings, but sugar processors as well, as they attempt to maintain an adequate supply of sugar beets from limited irrigated cropland acreage located near to the factories.

One of the developing technologies with potential for reducing costs and using expensive or hazardous inputs more efficiently is site-specific crop management, also know as precision agriculture. This approach involves the variable application of inputs such as fertilizer, water, or pesticides. This is based on sampling to determine variability in fertility, soil type, and pest populations, as opposed to a blanket or uniform rate of input. Some input suppliers and crop consultants have GPS-based sampling services to implement variable rate application. Increasingly, farmers have equipment with computers programmable for variable rates on-the-go. Often, the weak link in applying this technology for precision management occurs in programming the variable input rates. The interaction of pest populations, input application rates, and yield responses are needed to better program the variable rate applicators to avoid over- or under-application of costly inputs.

Site-specific technology could be especially useful with nematicides on sugar beets, since nematode populations are seldom distributed evenly over a field, nematicide is very costly, and sugar beets are a high value crop. In a review of previous site-specific studies, Swinton and Lowenberg-DeBoer (1998) indicate that variable rate applications may be more successful with higher valued crops such as sugar beets. More effective use of inputs such as nematicides could improve grower's profits and reduce environmental impact. This raises the question, "How much extra profit along with savings in nematicide usage are available from using variable rate technology?"

Objective

This article examines benefits of precision application in a case involving a higher valued crop (sugar beets) and costly input (nematicide) in terms of profitability and sugar production when fumigating nematodes at any one of several uniform rates, as opposed to adjusting the rate in response to different nematode populations.

Data and Methods

A 39-acre field managed for commercial sugar beet production in southeast Wyoming was grid-sampled for nematode populations in the early spring of 2000, in preparation for variable rate nematicide application. Locations for sampling nematode populations were identified at the center of the 3-acre grids with the assistance of GPS. Populations of nematodes were determined, and found to be highly variable, ranging from fewer than two to over twenty-three eggs/cm^3 of soil (Figure 1).

A whole-field comparison would have been preferred for analysis of uniform versus variable rate treatments. However, at the time of the study, there was not a yield monitoring sugar beet harvester in the area, thus prohibiting the collection of yield estimates in the grid areas. However, the on-site availability of equipment to apply nematicide on a variable rate basis provided a convenient opportunity to apply nematicide at different rates in established strips, from top to bottom of the 39-acre field, which had lower nematode populations in the lower north half of the field (Figure 1). An experimental area was flagged off within this same field to identify the relationship between sugar beet yield and different rates of Telone II®.

The experimental area was comprised of twenty-four plots (30 x 60 ft.) arranged in a rectangular manner, with three replication strips across and eight blocks deep, representing a 180 foot wide experimental strip from top to bottom of the 39-acre field (Table 1). Each of the twenty-four plots were sub-divided to allow the application of different rates of Telone II® (7.2, 9.5 and 14. 4 gallons/acre on a banded rate basis), as well as a no control treatment rate (0.0 gal/ac).[1] Before applying nematicide, the experimental plots were re-sampled for nematode infestation.

Figure 1. Location of an experimental strip for alternative nematicide rates in a commercial sugar beet field (39 acres), previously grid sampled (3-acre blocks) for sugar beet nematodes (eggs/cm3), April 2000 (Simplot Soilbuilders, Torrington, WY).

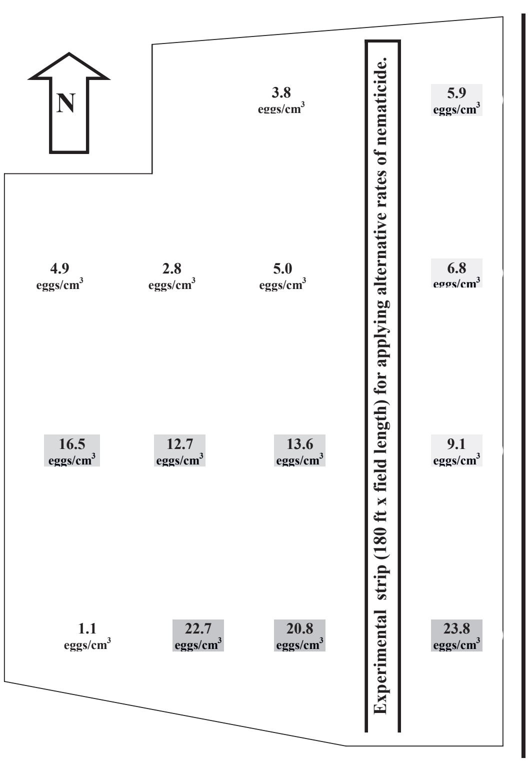

Table 1 shows the distribution of nematode populations in the experimental plots ranging from 1.1 to 14.5 eggs/cm^3. In general, larger nematode populations were located in the southern part of the field, consistent with 3-acre grid samples. However, the upper level of nematode populations (14.5 eggs/cm^3) within experimental plots was less than the upper level previously observed within the 3-acre field samples (over 20 eggs/cm^3).

After sampling, Telone II® was applied within experimental strips from top to bottom of the field at the specified rates on a banded basis, including none (no control rate); a lower suppression rate (9.5 gallons/acre) and the full-label rate (14.4 gallons/acre).

Sugar beets were planted in late April 2000 and harvested in early October. Samples of harvested sugar beets from each of the plots were analyzed at Holly Tare Lab (Torrington,

Table 1. Configuration of experimental plots (#1 - #24) with respect to distribution of nematode populations (1.1 to 14.5 eggs/cm3), and selected rates of nematicide.

180 feet

0.0 gal/ac · 9.5 gal/ac · 14.4 gal/ac	Field Length	0.0 gal/ac · 9.5 gal/ac · 14.4 gal/ac	Field Length	0.0 gal/ac · 9.5 gal/ac · 14.4 gal/ac
#1 5.7 eggs/cm^3		# 2 2.1 eggs/cm^3		# 3 3.0 eggs/cm^3
# 4 1.1 eggs/cm^3		# 5 2.1 eggs/cm^3		# 6 4.7 eggs/cm^3
# 7 2.4 eggs/cm^3		# 8 2.5 eggs/cm^3		# 9 9.1 eggs/cm^3
# 10 5.7 eggs/cm^3		# 11 5.4 eggs/cm^3		# 12 4.0 eggs/cm^3
# 13 4.6 eggs/cm^3		# 14 10.1 eggs/cm^3		# 15 7.5 eggs/cm^3
# 16 6.2 eggs/cm^3		# 17 6.2 eggs/cm^3		# 18 12.4 eggs/cm^3
# 19 6.9 eggs/cm^3		# 20 14.5 eggs/cm^3		# 21 7.8 eggs/cm^3
# 22 4.8 eggs/cm^3		# 23 8.0 eggs/cm^3		# 24 13.1 eggs/cm^3

Wyoming). Resulting sugar beet yields (tons/ac) associated with different rates of nematicide were recorded for each of the plots having different populations of nematodes (eggs/cm^3)

Low versus High Nematode Population Thresholds

In order to conduct an analysis of sugar beet yield response to alternative rates of nematicide with either low versus high populations of nematodes, the twenty-four experimental plots (Table 1) were sorted in ascending order of nematode populations (eggs/cm^3), and were then divided in half to create two equal subgroups of twelve plots. The first subgroup of twelve plots represented those having lowest nematode populations (1.1 to 5.7 eggs/cm^3), and the median value (5.7 eggs/cm^3) provided a threshold for defining an upper limit representing lower egg populations in the analysis, with the second subgroup of twelve plots above the median threshold became the basis for defining a range of higher egg populations in the analysis (5.7 to 14.5 eggs/cm3).[2] As shown in Table 2, average sugar beet yields (Col. 3) and sugar production (Col. 4) were then calculated for both the low and high nematode population subgroups (Col. 1), given different rates of nematicide (Col. 2).While sugar beet yields (tons/acre) were found to be a function of nematode populations (eggs/cm^3), no statistical relationship was found between nematode populations and percent sugar content (Opp,2001).

Results

The effectiveness of alternative nematicide rates was initially evaluated in terms of sugar production, value of production, and net return over specified variable costs(NROSVC). Next, the efficacy of uniform rates versus a variable rate was examined, given different proportions of nematode infestation across a representative field.

Table 2. Sugar beet yields, nematicide costs and net return (NR-OSVC) for various nematicide rates and population levels. [c]

1	2	3	4	5	6	7	8	9
		Production and Revenue			Specified Variable Costs			
						Harvest & Haul		
Nematode Populations eggs/cm^3	Nematicide Rates gal/ac	Beet Yield[a/] ton/ac	Sugar[b/] lb/ac	Gross Return[c/] $/ac	Nematicide[d/] $/ac	Beets[e/] $/ac	Total $/ac	NR-OSVC[f] $/ac
1 Lower egg Populations (1.1 - 5.7 eggs/cm^3)	0	27.2	7,616	883	0	136	136	**747**
	9.5	27.5	7,700	893	115	138	253	640
	14.4	29.2	8,176	948	166	146	312	636
2 Higher egg Populations (5.8 – 14.5 eggs/cm^3)	0	18.3	5,673	686	0	92	92	594
	9.5	22.7	7,037	851	115	113	228	**622**
	14.4	23.1	7,161	866	166	116	282	584

a / Sugar beet yields are an average of plot yields resulting from alternative rates of nematicide (0.0 or 9.5 or 14.4 gallons/acre); given spring exposure to either low (1.1 to 5.7 eggs/cm3) or high (5.7 to 14.5 eggs/cm3) nematode populations.

b / Sugar production (lbs/acre) is derived as the product of sugar beet yield (tons/acre) and average percent sugar: 14.0% given low nematode populations; and 15.5% given high nematode populations.

c / Gross return ($/acre) is derived as the product of sugar beet root yield (tons/ac) and sugar beet price ($/ton). Sugar beet price is derived from a sugar company contract, as a function of an average net sugar price ($24/cwt) for processors, and percent sugar, resulting in (1) a lower price of $32.46/ton, given 14.0% sugar associated with low nematode populations; and (2) a higher price of $37.49/ton, given 15.5% sugar associated with high nematode populations. These prices are lower than the $39/ton 10-year average price (1991-2000) received for sugar beets in Wyoming (Wyoming Agricultural Statistics), which is perhaps due to lower than average sugar content associated with the plot samples.

d / Nematicide cost ($/acre) is the sum of (1) cost of product, (Telone II®), calculated as the per gallon application rate, times the $10.43/gal. product price; and (2) a $16/acre cost of applying nematicide (Hewlett et al.).

e/ The added cost of harvesting &hauling extra sugar beets as a result of higher yields, is the product of sugar beet yield (ton/ac) times a $5.00/ton hauling& harvesting rate (Hewlett et al.).

f/ NR-OSVC is net return over specified variable costs(harvesting & hauling beets, nematicide material and its application. SINCE ONLY SOME COSTS (i.e. those associated with fumigation of nematodes),NR-OSVC IS NOT A TRUEMEASUURE OF PROFITABILITY, but by itself NR-OSVC overstates true profitability, which would need to include all the costs of growing sugar beets.

Sugar Beet Yields

How effective is nematicide for achieving higher yields? The added benefit of using nematicide depends upon the state of nematode infestation (Table 2). Applying nematicide to portions of the field with lower nematode populations (1.1-5.7 eggs/cm^3), provides only small yield benefits compared to no control, increasing from 27.2 tons/acre (no control) to only 27.5 and 29.2 tons/acre with nematicide (9.5 and 14.4 gallons/acre). However, with higher nematode populations (5.7-14.5 eggs/cm3), nematicide has a much greater impact. Mean beet yields increase from a low of 18.3 tons/acre (no control), to a high of 23.1 tons/acre applying a full-label rate of Telone II® (14.4gallons).

Gross Revenues

Table 2 shows that both sugar production (Col. 4) and gross revenue (Col. 5) are affected by sugar beet yield (Col. 3), and percent sugar content (which affects sugar beet price). In this case, higher yielding beets (associated with lower nematode concentrations), actually contain less sugar (14.0%). Conversely, lower yielding beets (subject to higher nematode populations) are compensated by a higher sugar content (15.5%).

For the purpose of deriving gross revenue, a lower contract price ($32.46/ton) is incurred with higher yielding but lower quality beets (14.0% sugar), and conversely, a higher price ($37.49/ton) is realized with lower yielding but higher quality beets (15.5% sugar). In general, higher rates of nematicide generate more sugar and gross revenue, but the effect is more pronounced in the face of higher nematode populations. For example, with higher nematode concentrations, a $180/acre gross return increase is realized from applying the highest rate of nematicide, 14.4 gallons ($866/acre), compared to no nematicide ($686/acre). However, given lower nematode populations, only a $65/acre gross return increase is realized from applying 14.4 gallons ($948/acre) compared to no nematicide ($883/acre).

Specified Variable Costs (SVC)

The Net Return over Specified Variable Costs (NR-OSVC) associated with alternative nematicide rates (Table 2, Col. 9) is derived as per acre gross return (Col. 5) minus total specified variable costs (Col. 8). Specified variable costs in this case, are those directly affected by type of nematicide application, including the purchase and application of nematicide, as well as the cost of harvesting and hauling higher yielding beets (Col. 6-8). It should be noted that the cost for a standard uniform application ($16 per acre) is less expensive than a variable rate application ($17 per acre). The $17/acre cost for variable application is based on (1) an additional $3/acre variable rate application charge ($19 vs. $16/acre); plus (2) a $14/acre charge for GPS mapping, soil sampling (every 3-acres) and lab analysis (Opp, 2001, p.64). The $17/acre estimate in this case could be conservative (or over-estimated) because in actual practice, it may not be necessary to incur the latter category of costs ($14/acre) on an annual basis since locations of nematode populations are believed to be relatively stable over time, perhaps making it unnecessary to repeat the costs of mapping and sampling each year. If so, it may be reasonable to annualize the $14/acre cost over a multi-year sampling cycle, if such a cycle could be verified, e.g., $14/4 years = $3.50/year.

Net Returns over Specified Variable Costs (NR-OSVC)

The Net Return over Specified Variable Costs (NR-OSVC) associated with alternative nematicide rates (Table 2, Col. 9) is derived as per acre gross return (Col. 5) minus specified variable costs (Col. 8). Specified variable costs in this case include only those which are different between the various rates of nematicide application 0.0 gal./acre, 9.5 gal./acre, and 14.4 gal./acre, including the purchase and application of nematicide, as well as the cost of harvesting and hauling higher yielding beets (Col. 6- 8).

Which rate of nematicide is most effective for profitability? NR-OSVC is net return over specified variable costs: harvesting and hauling beets, nematicide material, and its application NOTE: SINCE ONLY SOME COSTS are used to compute NR-OSVC (i.e., those associated with fumigation of nematodes), NR-OSVC IS NOT A MEASURE OF TRUE PROFITABILITY, but by itself NR-OSVC essentially overstates true profitability, which would need to include all of the costs of growing sugar beets. Table 2 shows NR-OSVC depends on the state of nematode infestation (Col. 9). Given *lower* nematode populations (1.1-5.7 eggs/cm^3), not applying any nematicide is best for achieving highest NR-OSVC ($747/acre). The small added revenue from applying either rate (9.5 or 14.4 gallons) is insufficient to cover additional costs.

With higher nematode populations (5.7-14.5 eggs/cm^3),[2] the lower suppression rate (9.5 gallons) is best ($622/acre), exceeding non-use by $28/acre ($594 vs. $622), and the full label rate (14.4 gallons) by $38/acre ($622 vs. $584). Although the full-label rate provides a slightly higher yield than the lower suppression rate (23.1 vs. 22.7 tons/acre), the extra cost of applying more nematicide (14.4 vs. 9.5 gallons) far outweighs its extra revenue.

In this case, if the sole objective is to produce the most sugar, simply applying nematicide at the highest rate (14.4 gallons) is best, regardless of whether nematode populations are low or high. However, if the goal is to maximize net return (NR-OSVC), the best choice is to: (1) not treat those portions of a field having nematode counts below a threshold of 5.7 eggs/cm^3,[2] and (2) apply nematicide at the lower suppression rate (9.5 gallons) to those portions of the field having nematode counts exceeding 5.7 eggs/cm^3.

Variable versus Uniform Rates

Average net return (NR-OSVC) and sugar production for variable rate application of nematicide are estimated on a whole-field basis for a moderately infested field in Table 3. Net return (NR-OSVC) and sugar production are compared between the remaining application rates (0.0, 9.5 or 14.4 gallons). Net return (NR-OSVC) from a variable rate application (Col. 1) is

Table 3. Net Return over specified costs(NR-OSVC) and sugar production as a result of using variable versus uniform rate applications, given: A MODERATELY INFESTED FIELD c/

	Types of Applications			
II	Variable	Uniform Rates b/		
ITEMS	Rate d/	None	9.5 gal	14.4 gal
	1	2	3	4
MODERATELY Infested Field c/				
(a) 50% of acres with lower egg populations (5.7 eggs/cm^3)				
NR-OSVC ($/ac)	$747	$747	$640	$636
Sugar (lb/ac)	7,616#	7,616#	7,700#	8,176#
(b) 50% of acres with				
NR-OSVC ($/ac)	$622	$594	$622	$584
Sugar (lb/ac)	7,037#	5,673#	7,037#	7,161#
NR-OSVC ($/ac)				
Weighted Field Average e/	$668	$671	$631	$610
Margin of benefit f/	-	$3	($37)	($58)
Sugar Production(lb/ac)				
Weighted Field Average e/	7,327#	6645#	7,369#	7,669#
Margin of benefit f/	-	-682#	42#	342#

a/ Lower nematode populations range from 1.1 to 5.7 eggs/cm3; and higher nematode populations range from 5.7 to 14.5 eggs/cm3.
b/ Profitability (net return) and sugar production associated with different uniform rates (col. 2 - 4) are derived from Table 2.
c/ Infestation percentages, (50% of acres in the lower nematode category; and 50% of acres in the higher nematode category), are representative of the distribution of nematode populations found within the 39-acre sugar beet field where field trials were conducted.
d/ Net return for variable rate (col. 1) is the highest net return option of the uniform rates (col. 2 - 4). Sugar production for variable rate, is that corresponding with highest net return option.
e/ Field average is a weighted average, based on the percentage of low nematode acreage (50%) and high nematode acreage (50%), as observed within the 39-acre field. Variable rate net return (col. 1) includes an added $17/acre cost for variable rate application.
f/ Margin of benefit of variable rate over uniform rate application, is net return (or sugar production) from any one of the uniform rates (col. 2 -4) minus net return (or sugar production) from variable rate (col. 1)

determined by: (1) selecting the best uniform rate (0.0, 9.5, or 14.4 gal./acre) for acreage lower populations (1.1-5.7 eggs/cm^3); and similarly, selecting the best uniform rate for acreage with higher populations (5.7- 14.5 eggs/cm3), and (2) calculating a weighted field average of the two optimum net return values. The field average is weighted by the percentage of acreage having higher populations (50%) and percentage of acreage having lower populations (50%).[3] The weighted average net return (NROSVC) for variable rate application (Table 3), is reduced by an additional $17/acre charge for variable rate application.[4]

How profitable is a variable rate treatment compared to various uniform rates? As described below, the effectiveness of variable versus uniform rate depends on the state of field infestation (moderate.light or heavy).

Alternative States of Field Infestation

To assess the impact of infestation intensity on variable rate profitability, three different field situations are considered: (1) Moderately Infested Field (Table 3), (2) Lightly Infested Field (Table 4), and Heavily Infested Field (Table 5).

Moderately Infested

The first field (Table 3) is an example of a moderately infested field, with half of the acreage (50%) having lower nematode populations (1.1 to 5.7 eggs/cm^3), and the remaining acreage (50%) having higher nematode populations (5.7 to 14.5 eggs/cm^3), which in this case typifies the proportions of infestation in the experimental thirty-nine acre field. Which uniform rate is best for achieving maximum profitability and highest sugar production for a moderately infested field? The bottom of Table 3 (Col. 2-4) shows that not applying nematicide offers a higher average net return or NR-OSVC($671/acre) than

Table 4. Net Return over specified costs (NR-OSVC) and sugar production as a result of using variable versus uniform rate applications, given a field situation that is LIGHTLY INFESTED a/

	Types of Applications			
Field Situation	Variable Rate a/	None	9.5 gal	14.4 gal
	1	2	3	4
a LIGHTLY Infested Field c/ (80% of field acreage has low eggpopulations & only20 % hashigh egg populations				
NR-OSVC ($/ac)80%	$747	$747	$640	$636
Sugar Production (lb/ac)	7,616#	7,616#	7,700#	8,176#
NR-OSVC ($/ac)20%	$622	$594	$622	$584
Sugar Production (lb/ac)	7037#	5,673#	7,037#	7,161#
Net Return ($/ac)				
Weighted Field Average b/	$705	$716	$636	$626
Margin of benefit c/	–	$11	($69)	($79)
Sugar Production (lb/ac)				
Weighted Field Average d/	7,500#	7,227#	7,567#	7,973#
Margin of benefit e/	–	-273#	67#	473#

c Net return for variable rate (col. 1) is the highest net return option of the uniform rates (col. 2 - 4). Sugar production for variable rate, is that corresponding with highest net return option.

d/ Weighted field averages for net return and sugar are calculated in the same manner as previously shown in Table 3, except the percentage weights are revised from 50% low and 50% high nematode acreage (representative field), to 80% low and 20% high nematode acreage (lightly infested field); and 20% low and 80% high nematode acreage (heavily infested field).

e/ Margin of benefit of variable rate over uniform rate application, is net return (or sugar production) from any one of the uniform rates (col. 2 -4) minus net return (or sugar production) from variable rate (col. 1) either 9.5 gallons ($631/acre) or 14.4 gallons ($610/acre). However, average sugar production without nematicide (6,645 lbs.) is much lower than applying 9.5 gallons (7,369 lbs.) or 14.4 gallons (7,669 lbs.).

How profitable is a variable rate treatment compared to various uniform rates? Variable rate (after accounting for an additional $17/acre charge), offers a slightly lower field average NR-OSVC ($668/acre), but only by a narrow margin ($3/acre) under not applying nematicide ($671/acre). However, if a grower believes it is necessary to apply nematicide, the margin of benefit for variable rate application is much better than either of the uniform rates. Specifically, variable rate generates a higher net return ($668/acre) than the best 9.5 gallon uniform rate ($631/acre), representing a $37/acre margin of benefit ($768-$631/acre). The margin of benefit over the full-label rate (14.4 gallons) is even better ($58/acre).

Lightly Infested

What is the best option given a lightly infested field with most of its acreage (80%) having LOWER nematode populations (Table 4)? In this case, no control over the entire field (Col. 2) offers the best NR-OSVC ($716/acre), relative to applying either 9.5 gallons ($636/acre) or 14.4 gallons ($626/acre). However, per acre sugar production again is compromised with no application (7,227 lbs.), compared to 9.5 gallons (7,567 lbs.) or 14.4 gallons (7,973 lbs.).

After accounting for the additional cost ($17/acre) to implement variable rate technology, its net return for a lightly infested field is again worse ($11/acre) than not applying nematicide ($705 vs. $716/acre). But again, if a grower believes it is necessary to apply nematicide, perhaps from the standpoint of maintaining sugar production, variable rate is a better option. Variable rate yields more sugar than not applying nematicide (7,500 versus 7,227 lbs./ac). Moreover, variable rate generates higher NR-

Table 5. Net Return over specified costs (NR-OSVC) and sugar production as a result of using variable versus uniform rate applications, given a field situation that is HEAVILY infested. a/

Field Situation	Types of Applications: Variable Rate a/	None	9.5 gal	14.4 gal
	1	2	3	4
HEAVILY infested Field Only 20% of field acreage has LOW eggs populations & 80 % has HIGH egg populations				
NR=OSVC ($/ac) 20%	$747	$747	$640	$636
Sugar Production (lb/ac)	7,616#	7,616#	7,700#	8,176#
80%	$622	$594	$622	$584
Sugar Production (lb/ac)	7,037#	5,673#	7,037#	7,161#
NR=OSVC ($/ac)				
Weighted Field Average b/	$630	$625	$626	$594
Margin of benefit c/	–	($5)	($4)	($36)
Sugar Production (lb/ac)				
Weighted Field Average d/	7,153#	6,062#	7,170#	7,364#
Margin of benefit e/	–	-1,091#	17#	211#

c Net return for variable rate (col. 1) is the highest net return option of the uniform rates (col. 2 - 4). Sugar production for variable rate, is that corresponding with highest net return option.

d/ Weighted field averages for net return and sugar are calculated in the same manner as previously shown in Table 3, except the percentage weights are revised from 50% low and 50% high nematode acreage (representative field), to 80% high and 20% low egg populations.

e/ Margin of benefit of variable rate over uniform rate application, is net return (or sugar production) from any one of the uniform rates (col. 2 -4) minus net return (or sugar production) from variable rate (col. 1)

OSVC ($705/acre) than blanket applications of either 9.5 gallons ($636), or 14.4 gallons ($626), representing substantial margins of benefit equal to $69 to $79/acre, largely the result of savings in cost for nematode material.

Heavily Infested

Table 5 represents a more severely impacted field with most of its acreage (80%) having higher nematode populations. What is the best choice given a heavily infested field? The bottom of Table 5 shows that in this instance, variable rate is slightly better than not treating, by a margin of $5/acre ($630 vs. $625/acre). However, the margin of benefit from using variable rate technology versus traditional uniform rate applications decreases sharply when moving from a lightly infested field (Table 4) to a more heavily infested field (Table5). For example, using a uniform 9.5 gallon rate as a point of comparison (Col. 3), the benefit margin of using variable-rate technology falls from $69/acre (lighter infestation), to only $4/acre (heavier infestation). Likewise, given a full-label rate (14.4 gallons), the margin shrinks from $79/acre to only $36/acre. Essentially, the potential for wasted input from blanket applications is greatest when nematodes occupy only small portions of a field. However, when most of the field is heavily infested, the extra cost of implementing variable rate technology may not be worthwhile compared to a traditional blanket application.

Conclusion

This study was initiated to examine the merits of adjusting nematicide application rates to different levels of nematode populations. Not applying any nematicide emerged as the best choice in the face of lower nematode populations. The alternative supplemental label rate (9.5 gal/ac) was best for higher profit in the face of higher nematode populations. The extra yield and revenue benefit of applying a full label rate (14.4 gal/ac rate) was small in this case, and not worth the extra cost. However, the benefit of applying the full label rate may have been more pronounced if the experimental plots had contained higher populations of nematodes as observed with the 3-acre field samples. Nevertheless, in actual practice, the lower 9.5 gallon suppression rate has been observed to be a common choice for many growers in the region.

As opposed to blanket applications of nematicide at rates of either 9.5 or 14.4 gallons/acre, adjusting the rate from no nematicide (given lower nematode populations) to 9.5 gallons (given higher nematode populations), provided modest, although not huge, improvements in profitability. Indeed, in extreme situations, a case could be made for not implementing variable rate technology with its higher cost, since not applying nematicide was usually more profitable in the case of lightly infested fields while a blanket application appeared to be better in the case of a heavily infested field.

Sensitivity to cost of Nematicide and price of sugar beets.

Variable rate technology appears to provide a viable alternative to traditional uniform rate applications for applying nematicide in sugar beet fields as a means to assure higher profitability and better levels of sugar production. Based on an initial earlier sensitivity analysis of variable rate application, Opp notes, "The effectiveness of variable rate is very dependent on the expected price for sugar beets and may not be feasible if future prices erode to levels below $40/ton"(Opp, 2001, p.68). In addition, "the price of nematicide is found to be a very influential factor"(p.58).

In addition to grower profitability, environmental factors are extremely important in assessing the worth of variable rate technology, especially in the case of nematicide. Indeed, adverse environmental costs are associated with fumigation for nematode control, and these were not factored into the calculation of profitability. If these hidden costs could be more easily quantified and measured, the benefit of variable rate technology could be even better. Hidden costs include applicator's health and safety, water, and air pollution as well as adverse impacts on beneficial non-target soil organisms. Variable rate, as portrayed in this study, provides for very significant reductions in product usage and associated environmental costs, while maintaining grower's profitability. For example, in the case of a representative field, with only 50 percent of its acreage needing fumigation because of higher nematode populations, composite product usage on a whole-field per acre basis could drop from either 9.5 to 4.8 gallons/acre (suppression rate) or from 14.4 to 7.2 gallons/acre (full-label rate). Therefore, from the standpoint of environmental benefits, a very compelling argument can be made for using variable rate technology as a substitute for a blanket application, even though improvements in grower profits are estimated to be modest at best.

It is recognized that results and conclusions of this study are restricted to one location and one year of sampling. In addition, sampling and results were limited to smaller field plots as opposed to the more typical three acre blocks. Nevertheless, it appears that variable rate technology has the potential to be a very worthwhile alternative to traditional blanket applications of costly and hazardous inputs such as nematicide.

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Endnotes

1 A lower rate of Telone II® (7.2 gallons/acre) was applied in the study, but proved to be ineffective for nematode control, and therefore was not meaningful for economic analysis (Opp, 2001). For purpose of brevity, this rate is not considered in this analysis.

2 (The lower population category (1.1-5.7 eggs/cm3) is very close to an economic threshold of 5.0 eggs/cm3, reported by Robb et al.(p. 40), assuming 80% control effectiveness for nematicide, 15% sugar and $21/cwt sugar price, and cost of control equal to $120/acre.

3 Infestations percentages, 50% of acreage with lower nematode populations (1.1 to 5.7 eggs/cm3), and 50% of acreage with higher nematode populations (5.7 to14.5 eggs/cm3), are representative of the distribution of nematode populations found in the 39-acre sugar beet field where the field trials were conducted.

4 The $17/acre cost for variable application is based on (1) an additional $3/acre variable rate application charge ($19 vs. $16/acre); and (2) a $14/acre charge for GPS mapping, soil sampling (every 3-acres) and lab analysis (Opp, 2001). The $17/acre estimate in this case could be conservative. In practice, it may not be necessary to incur the latter category of costs ($14/acre) on an annual basis, since locations of nematode populations are believed to be relatively stable over time. If so, it may be reasonable to amortize the $14/acre cost over a multi-year sampling cycle, if such a cycle could be verified, e.g., $14 / 4 years = $3.50/year.

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