TRAP CROP RADISH: A SUSTAINABLE ALTERNATIVE FOR NEMATICIDE IN SUGAR BEETS *

By

Larry J. Held, James W. Jennings, David W. Koch and Fred A. Gray**

Presented at Western Agricultural Economics Association Annual Meeting
July 11-14, 1999
Fargo, ND

---

* Paper for presentation at the annual meeting of the Western Agricultural Economics Association, July 11-13, 1999. North Dakota State University, Fargo, ND.

** Professor and former Graduate Research Assistant in the Department of Agricultural and Applied Economics; and Professors in the Department of Plant Sciences, respectively, University of Wyoming.

Trap Crop Radish: a Sustainable Alternative for Nematicide in Sugar beets

ABSTRACT

Chemical treatment of nematodes in sugar beets can be very costly ($190 per acre), and hazardous, representing significant environmental risks to air, water and human health. Substituting trap crop radish for chemicals, represents a win-win case of sustainable pest control, yielding environmental benefits, higher profit and reduced risk.

The merits of sustainable farming practices continue to receive considerable attention in agricultural research and management. Lyman and Pederson note some common elements associated with sustainable systems including lower usage of pesticides and fertilizer inputs, and special cultural practices and crop rotations. Environmental benefits are often realized from implementing sustainable practices, however, reduced net revenue and/or greater risk are potential drawbacks which might discourage adoption. This paper examines environmental benefits, potential profitability and risk associated with incorporating a special type of radish (trap-crop) into sugar beet and malt barley rotations, to replace traditional chemical treatment of nematodes.

Background

Sugar beets (*Beta vulgaris*) are a high-valued, but also a high-cost specialty crop with a national average production cost of $804 per acre (USDA-ERS, 1996). Astute cost and production management is critical for maintaining favorable profit margins, particularly from the standpoint of effective weed and pest control.

The sugar beet cyst nematode (*Heterodera schachtii*), a microscopic roundworm is among the most damaging of sugar beet pests. Continuous feeding by large numbers of nematodes and the release of a toxin into sugar beet roots can cause poor stands and severely reduced yields. Steele reports its presence in 17 sugar beet producing states, and 40 countries worldwide. To date, control can be achieved with longer rotations which incorporate non-susceptible crops in place of sugar beets, or by using expensive chemical treatments. Resistant sugar beet cultivars would be an ideal control, however, resistant cultivars are not currently available (Lange and De Bock). Longer rotations (five to six years out of sugar beets) can effectively reduce nematode populations below damage thresholds. Unfortunately, longer rotations are not nearly as profitable as planting sugar beets on the same ground every third year. Few if any crops can match sugar beets in terms of their high earning potential.

Chemical treatments for nematode control (aldicarb, 1,3-dichloropropene, or terbufos) and can be quite effective on an annual basis, but are also very costly and hazardous to apply. The per acre cost of applying these chemicals at recommended rates varies from $50 to $190 per acre (Jennings). In addition, these pesticides are restricted-use chemicals and represent a significant environmental risk to air and water, as well as a health risk to applicators (Thomason). Moreover, future availability of these materials is uncertain, therefore threatening the sustainability of the sugar beet industry.

To address these concerns, research has been conducted in several sugar beet producing states to evaluate the biological effectiveness of growing "trap crops" in the form of special varieties of radish (*Raphanus sativus*) or mustard (*Sinapis alba*) for nematode control (Koch and Gray, Kerr et. al. and Hafez),. A trap crop to control nematodes is planted one year prior to planting sugar beets. It effectively cleanses the soil by first attracting nematodes to enter its roots, and then becomes an antagonistic host by preventing nematodes from reproducing. Research in northwest Wyoming has shown that traps crops can reduce nematode populations by up to 75 percent, resulting in as good or better sugar beet yields than attained from chemically treated acres (Koch and Gray). However, less is known about their economic potential as a substitute for nematicide.

Approach

To address this question, an economic analysis was conducted for a representative irrigated sugar beet and malt barley operation in northwest Wyoming, as originally developed by a panel of farmers for Agee (1986); and subsequently updated by Jennings (1998). As shown in Figure 1a, the analysis centered on comparing a typical nematicide control treatment (#1) with two alternatives incorporating trap crop radish in a 720-acre rotation of sugar beets with malt barley. These alternatives include growing radish as either a full season crop (#2); or as a second crop following malt barley (#3). Based on historic prices and county average crop yields (Wyo. Agric. Stat.), whole farm profitability (and income variability) were calculated for each of the three crop rotations on a 12-year annual and average basis (1985-96) to consider both profitability and risk.

An important secondary benefit from growing trap crop radish, is its potential to supply late season forage for grazing lambs, as opposed to simply plowing radish down prior to planting sugar beets (Figure 1b). Studies of lambs grazing trap crop radish in northwest Wyoming have been very promising (Yun). Specifically, lambs have shown late season gains from trap crop radish ranging from 0.34 to over 0.37 lbs. per day, yielding up to 200 lbs. of gain and over 500 lamb grazing days per acre. Moreover, grazing radishes does not adversely affect nematode control or sugar beet yields.

To measure the contribution from grazing lambs, enterprise budgets were developed for purchasing lambs at an average weight of 85 lbs. in early October; and then selling 140 lb. fed lambs 150 days later (in early March). This represents an average daily gain of 0.37 lbs. over the entire time, including an initial grazing component

(October and November), and final feedlot component (December through March). Lamb grazing budgets were developed, either with or without trap crop radish. If lambs are grazed without trap crop radish in the rotation (Figure 1, 1b), at least 3,400 head can be carried on 240 acres of beet tops and barley stubble for 45 days through mid-November (Rule et al., and Agee, 1983). After this time lambs are placed in a feedlot to receive a free choice of alfalfa and corn for an additional 105 day (through early March) to achieve the target sale weight of 140 lbs.

If lambs are grazed with trap crop radish included in the rotation (Figure 1- 2b & 3b), growing 240 acres of radish will provide an extra benefit of extending the grazing season by at least 28 days for the 3,400 lambs, based on: (1) average radish production for grazing of 2,583 lbs. per acre, and a forage utilization rate of 69 percent (Yun); and average daily feed consumption of 4.5 lbs. per head (National Academy of Sciences). This provides a substantial cost savings of 28 fewer days in the feedlot, starting later in mid-December (as opposed to mid-November), and then extending to early March, thus requiring only 77 days (versus a full 105 days) of feeding purchased corn and alfalfa. Yearly profit margins for lambs were also calculated over a 12-year period (1985-96) based on historic prices for: (1) buying feed (Wyo. Agric. Stat.); and (2) purchasing 85 lb. feeder lambs in October, and selling 140 lbs. fed lambs in March (USDA, Ag. Mktg. 1997). Annual profit margins for lambs were then added to annual net revenue from crops to obtain a composite whole-farm annual and 12-year average return to land.

Profitability and Risk of Alternative Systems

Table 1 shows yearly and average net returns (1985-96) on a whole-farm basis, as well as selected measures of income variability (standard deviation) and downside risk. Downside target risk is measured by (1) the frequency (i.e. years in 12); and (2) the total amount that annual income misses an income target equal to $54,000 (representing a 5% rate of return to land) over the 12 year period (1985-96).

Trap Crop Radish: Crops-Only How attractive is replacing nematicide with trap crop radish? Table 1 shows the traditional 240-acre sugar beet and 480-acre malt barley rotation with nematicide (1a) generates a return to land equal to $41,766 (3.87%). This traditional rotation also misses the $54,000 target in five of 12 years, by a total of $245,408. Compared to nematicide, full season radish (2a) is a poor choice, yielding a return to land of only $10,677 (0.99%), due to: (1) its high production cost ($221 per acre); and (2) reduced barley revenue, and higher per acre machinery costs from growing barley on only 240 versus 480 acres. Full season radish is ineffective, not only from the standpoint of very low earnings ($10,677), but also in missing the $54,000 target in 11 of 12years, by a total of $522,362.

How effective is second crop radish ? Replacing nematicide with 240 acres of second crop radish (3a) is very attractive, generating a higher net return of $62,962 (5.83%) versus $41,766 (3.87%) from nematicide. This is the result of saving $165 per acre from not having to purchase and apply nematicide ($663 vs. $828). This far exceeds the added $74 per acre cost of growing second crop radish after barley ($438 vs. $364). Actually, second crop radish (3a) is better from both standpoints. It is more profitable than nematicide (5.83% vs. 3.87%), but moreover, less risky as well, in missing the $54,000 (5%) target in only three (vs. five) of 12 years; and by a total of $150,937 (vs. $245,408).

Trap Crop Radish: with Lambs How economical is replacing nematicide with trap crop radish when grazing lambs is normally part of the farming system. Table 1 shows that when lambs are grazed solely on beet tops and barley straw, i.e., without trap crop radish (1b), the return to land equals $53,140 (4.92%). With lambs, full-season radish provides an extra 28 days of grazing. Full season radish is nearly as profitable $49,542 (4.59%) as nematicide $53,140 (4.92%); and each exhibits a similar downside risk in missing the $54,000 in seven of 12 years by a total of just over $300,000. Growing radish as a second crop is, however, the very best option when grazing lambs (3b). The return to land nearly doubles $102,037 (9.45%) compared grazing lambs on only beet tops and barley stubble $53,140 (4.92%). Even better with second crop radish, downside risk is drastically reduced, in terms of missing the $54,000 (5%) target in only two (vs. seven) years in 12; and by a much smaller amount ($82,821 vs. $303,097).

The economic advantage of replacing nematicide with trap crop radish may be conservative in this analysis from two standpoints. First, the cost of nematicide is based on a rate below label recommendations (70%), to better represent area producer practices. Second, because of measurement difficulties, no long-term yield advantage was credited to trap crop radish, even though statistically higher yields have been occasionally observed with trap crop treatments compared to a nematicide (Koch and Gray).

Grazing Lambs: With or Without Radish What are the benefits of grazing (vs. not grazing) lambs with respect to profitability and risk (1b, 2b, and 3b vs. 1a, 2a, and 3a)? Without trap crop radish (and a longer grazing season), adding 3,400 lambs (1b vs. 1a) generated only a modest increase in the return to land (4.92% vs. 3.87%). Moreover, the added return was accompanied by extra income variability (standard deviation of $62,182 vs. $41,766), an increased risk of missing the $54,000 target in seven (vs. five) years in 12, and missing the target by a much larger amount $303,097 (vs. $245,408). However, if a farmer elects to grow trap crop radish for nematode control (either full season or second crop), adding lambs (given the extra grazing capacity) now provides a dual reward of not only increasing profitability, but reducing risk at the same time. For example, adding lambs when growing full season radish (2b vs. 2a) reduced the risk of missing the $54,000 (5%) target from eleven to seven years in 12 ; and by a reduced total amount of $312,348 (vs. $522,363). Similarly, adding lambs with second crop radish (3b vs. 3a.), reduced the frequency of missing the $54,000 target (from three to two years in 12), as well as the aggregate target loss (from $150,937 to $82,821).

Preference by Type of Risk Attitude To extend the analysis of downside risk, cumulative probability distributions (CPDs) were developed for each of the 12-year income streams shown in Table 1, first for systems without lambs (Figure 2, 1a-3a); and second, for systems including lambs (Figure 3, 1b-3b). Each CPD shows the probability (vertical axis) of net returns falling below a given amount (horizontal axis). Therefore, as opposed to focusing on the frequency of falling below a "single" target (e.g. $54, 000), Figures 2 and 3 provide the same information for multiple targets (ranging from a low of -$120,000 to a high of $220,000). Relative to Table 1, Figure 2 verifies the probability of net return falling below the $54,000 (5%) target, when growing second crop radish (3a) is quite low (25%), with a 100% probability that income will fall below the maximum observed return of $101,972 (1988); and a zero percent risk that income will fall below the minimum observed level of -$69,021 (1994). Similarly, the risk of falling below the $54,000 target is much higher (42%) when using nematicide (2a), but even higher (92%) if growing full season radish (1a) for nematode control.

To analyze which of the options is most preferred with respect to different types of risk attitudes, their respective 12-year net return distributions (Table 1), were tested within a first-degree (FSD) and second-degree (SSD) stochastic dominance framework (Goh et al.). FSD is applicable for all types of decision-makers (risk-averse, risk-neutral, and risk-seeking), based on the assumption of preferring more income to less. SSD is a more restrictive criteria confined to only risk-averse decision-makers.

Figure 2 shows second crop radish (3a) lies entirely below and to the right of both nematicide (1a) and full season radish (2a), showing its dominance by FSD, and its strong preference by all types of decision-makers. It not only exhibits a lower probability of falling below the $54,000 target, but all other possible targets as well. In addition, full season radish (without lambs) is shown to be a very poor choice for all types of decision-makers (FSD), in being dominated by not only second crop radish (3a), but nematicide (1a) as well. If lambs are included with the farming system (Figure 3), second crop radish (3b), again dominates both nematicide (1b) and full season radish (2b) by FSD.

Finally, how risky is choice of integrating lamb grazing with the farming system? Corresponding CPDs from Figure 2 (without lambs), and Figure 3 (with lambs) were tested with both FSD (all types of decision-makers) and SSD (risk-averse only). Compared to not grazing lambs at all (Figure 2, 1a), grazing lambs is more profitable, even when nematicide is used instead of trap crop radish (Figure 3, 1b). Specifically, by grazing lambs, the return to land increased from $41,766 to $53,140; overall low income was raised from -$90,217 to -$76,748; while overall high income was likewise elevated from $80,776 to $140,086. However, the addition of lambs "without" trap crops also increased the standard deviation of income over the 12-year period (from $46,570 to $62,182), as well as generating more downside risk in missing the $54,000 more frequently, and by a larger amount. Testing with SSD confirmed that without trap crop radish, a risk averse producer would not have a clear preference for grazing lambs (Figure 3, 1b) over not grazing lambs (Figure 2, 1a), and vice versa.

If a farmer elects to grow trap crop radish for nematode control, adding lambs increases the return to land by even a larger margin, with either full season ($10,677 to $49,542) or second crop radish ($62,962 to $102,037) . Moreover, as noted above, downside risk of missing the $54,000 target actually declines as a result of adding 3,400 lambs, when growing trap crop radish. A preference for "adding lambs" when growing either full season radish (2b vs. 2a) or second crop radish (3b vs. 3a) was established for not only those who are risk averse, but for all types of decision-makers as well (FSD).

Conclusions

The 1996 Farm Bill provides greater opportunities for farmers to try new and alternate crops than in the past. There continues to be encouragement for the concepts of sustainability, integrated pest management and conservation of natural resources. Growing trap crop radish represents a potential win-win case of adopting a sustainable pest control practice which does not necessarily compromise profitability or compound risk. Indeed, dual benefits of added profit in conjunction with lower risk are possible if trap crop radish can be grown as a second crop with an early harvested companion crop already in the rotation. To date, some growers have already experienced success with growing trap crop radish on limited acreages in Wyoming, Idaho and Colorado.

If an early harvested companion crop is not currently in the rotation, the benefits of second crop radish may be less certain, since the existing rotation would have to be changed. The economic success of full season radish depends largely on grazing livestock to defray its high cost. This may not be a major concern for operations currently integrating crops and livestock. Indeed, the additional fall forage supplied by trap crop radish makes grazing lambs more attractive even for risk averse producers.

Yet, some farmers prefer to operate on cash- crop basis, and may be less interested in adding livestock because of higher initial start-up and management costs.

Reduced ground water contamination and improved air quality are some important environmental advantages of shifting away from using nematicides that are not factored into this analysis. Besides supplying valuable fall grazing, trap crop radish also renders a number of other important benefits. Trap crop radish can recover residual soil nitrates from deeper soil profiles, thus promoting reduced ground water pollution and making additional nitrogen available for subsequent crops. Plowing down trap crop radish (whether grazed or not) also increases soil organic matter, which may well explain some of the increased sugar beet yield advantage observed from growing a trap crop in place of nematicide. Over the longer term, better nematode control may also occur, since increased organic matter can promote an increase in naturally occurring antagonists and parasites of the sugar beet nematode.

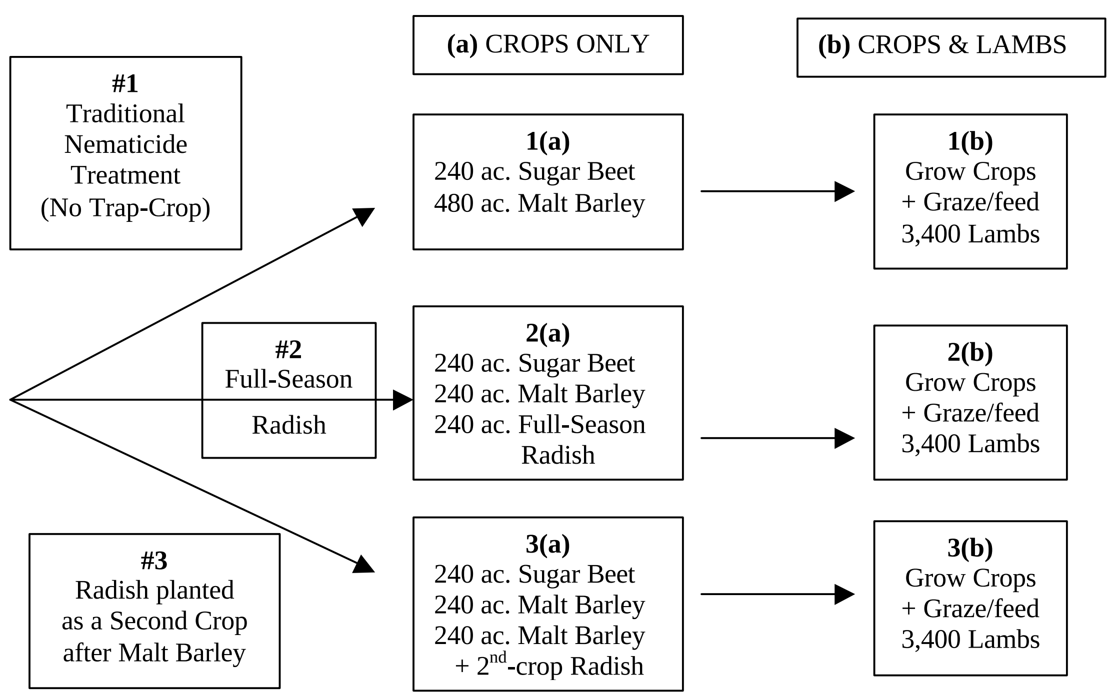

Figure 1.   Alternative Farming Systems, Either Without (#1) or With (#2 & #3) Trap-Crop Radish; and (a) Excluding or (b) Including Grazing/Feeding Lambs.

Table 1. Income and Risk Measures by Alternative Farming Systems for Controlling Sugarbeet Nematodes.

Year	Nematicide		Full-Season Radish		Second-Crop Radish	
	(1a) Crops Only	**(1b)** Crops & Lambs	**(2a)** Crops Only	**(2b)** Crops & Lambs	**(3a)** Crops Only	**(3b)** Crops & Lambs
	$	$	$	$	$	$
1985	62,736	40,134	18,311	26,236	83,932	92,067
1986	42,373	127,157	1,935	110,334	63,568	172,177
1987	65,326	94,060	31,772	83,348	86,522	138,307
1988	80,776	80,185	56,484	88,218	101,972	133,916
1989	56,232	49	26,908	1,747	77,428	52,478
1990	73,716	23,484	28,776	6,699	94,912	73,045
1991	25,116	30,990	(425)	31,231	46,312	78,178
1992	64,566	140,086	26,743	128,388	85,762	187,617
1993	73,248	29,304	32,232	15,274	94,444	77,696
1994	(90,217)	(76,748)	(91,448)	(49,936)	(69,021)	(27,299)
1995	12,575	27,689	(7,953)	34,401	33,771	76,335
1996	34,744	121,291	4,786	118,568	55,940	169,933
12-yr Average Inc. ($)	**41,766**	**53,140**	**10,677**	**49,542**	**62,962**	**102,037**
Standard Deviation ($)	46,570	62,182	36,837	55,279	46,570	61,149
Rate of Return to Land	**3.87%**	**4.92%**	**0.99%**	**4.59%**	**5.83%**	**9.45%**
Freq. (yrs/12) or { pct.} that annual income is below the $54,000 (5%) income target (1985-96) *	5/12 {42%}	7/12 {58%}	11/12 {92%}	7/12 {58%}	3/12 [25%}	2/12 {17%}
Total amount that annual income misses the $54,000 target, from 1985-96 ($) *	245,408	303,097	522,362	312,348	150,937	82,821

* To illustrate, 3(b) missed the $54,000 target in only two of 12 years (i.e. $52,478 - $54,000 = -$1,552 in 1989; and -$27,299 - $54,000 = -$81,229 in 1994), for a total amount of $82,821.

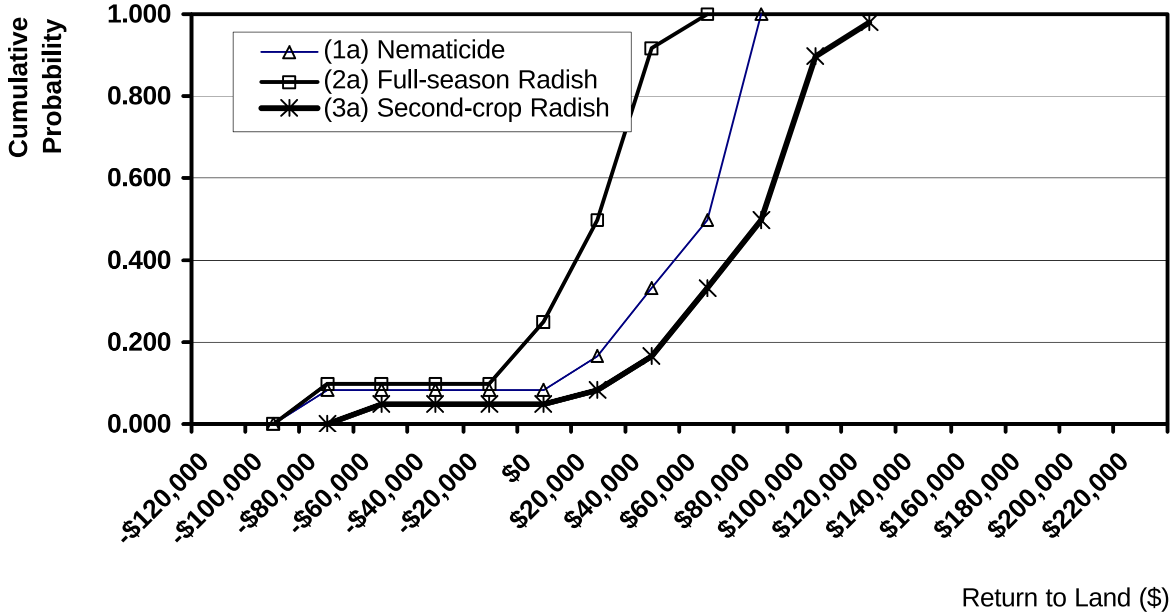

Figure 2. Probability of Net Return Falling Below Specified Amounts, Given Alternative Treatments for Nematodes: No Grazing Lambs.

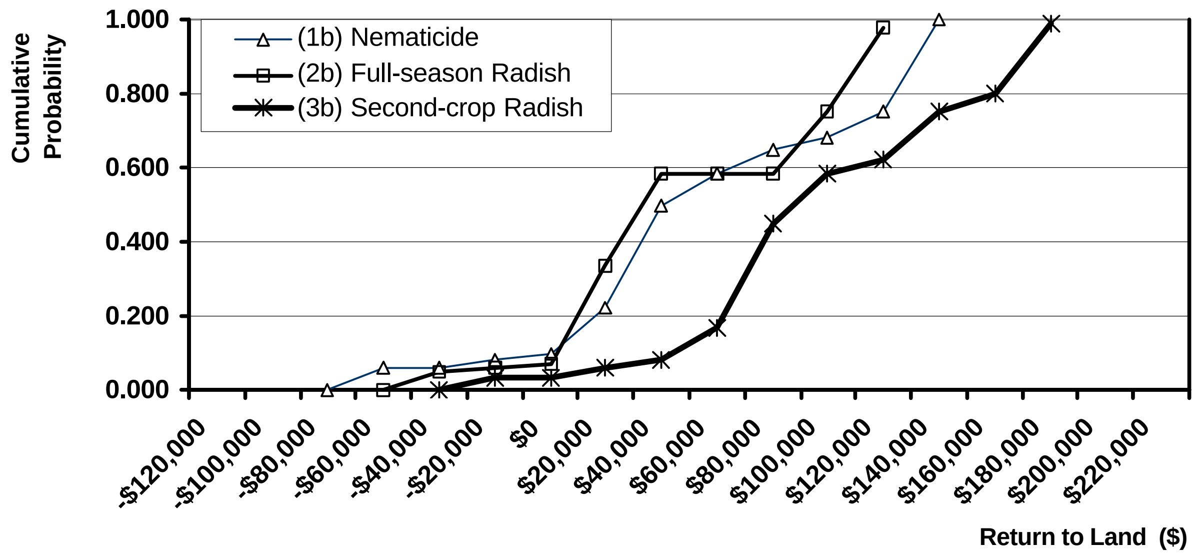

Figure 3. Probability of Net Return Falling Below Specified Amounts, Given Alternative Treatments for Nematodes: With Grazing Lambs.

References

Agee, D.E. "Possible Returns from Beet Tops, a Case Situation." Wyo. Coop. Ext. Serv. Ag. Econ. handout series , University of Wyoming, 1983.

Agee, D. E. "Costs of Producing Crops, Worland Area." Wyo. Coop. Ext. Serv. Bull. No. 644R, University of Wyoming, 1986.

Goh, S., C. Shih, M.J. Cochran and R. Raskin. "A Generalized Stochastic Dominance Program ". *South. J. Agric. Econ*., 21(1989):175-182.

Hafez, S.L. "The Use of Green Manure Crops in a Sugarbeet Rotation for Sugarbeet Cyst Nematode Management. *J. Nematol.*26(1994):548.

Kerr, E.D. R.G. Wilson, and D.D. Baltensperger. " Comparison of Several Trap Crop Species on Soil Populations of *Heterodera schachtii*. *J. Sugar Beet Research* 32(1995):147.

Koch, D.W. and F.A. Gray. "Nematode-Resistant Oil Radish for Control of *Heterodera schachtii* I. Sugarbeet-Barley Rotations." *J. Sugar Beet Research* 34(1997):31-43.

Jennings, J.W. "Economics of Integrating Nematode-Resistant Radishes and Lamb Enterprises with Sugar Beet Rotations in Northwest Wyoming." M.S. Thesis, University of Wyoming, 1998.

Lange, W. and Th.S.M. DeBock. "Pre-breeding for Nematode Resistance in Beet." *J. Sugar Beet* Research 31(1994):13-26.

Lyman, B.E. and G.D. Pederson. "Adoption of Sustainable Farm Practices: A Case Analysis. " *J. Amer. Soc. of Farm Mgrs. and Rur. Apprais.* 55(1991): 65-74.

National Academy of Sciences. "Nutrient Requirements of Sheep", 5th ed., Washington, D.C. 1975.

Robb, J.G. E.D. Kerr and D.E. Ellis. "Factors Affecting the Economic Threshold for *Heterodera schachtii* Control in Sugar Beet". *J. Sugar Beet Research* 29(1992):31-43.

Roberts, P.A. and I.J. Thomason. "Sugar Beet Pest Management: Nematodes." Univ. Cal., Div. of Agr. Sci. Special Pub. 3272. 1981.

Rule, D.C., D.W. Koch, R.R. Jones and C.J. Kercher. *Brassica* and Sugarbeet Forages for Lambs-Growth Performance of Lambs and Composition of Forage and Dock-Fat Fatty Acids." *J. of Prod. Agric.* 4(1991)29-33.

Steele, A.E. "Nematode Parasites of Sugar Beets." *Plant and Insect Nematodes*. ed. W.R. Nickle, pp. 507-569. New York: Marcel Dekker, 1984.

Thomason, I.J. "Challenges Facing Nematology: Environmental Risks with Nematicides and the Need for New Approaches. pp. 469-77. In J.A. Veech and D.W. Dickson (eds.): Vistas on Nematology. Society of Nematologists. 1987.

U.S. Department of Agriculture. "Livestock Detailed Annual Price Quotations: Fort Collins/Direct Sheep for 1982-96. Agric. Mktg. Serv. Lvstk. And Seed Div. 1997.

U.S. Department of Agriculture. "Sugar Beet Costs and Returns: 1996-97 Costs of Production." Econ. Res. Serv. 1998.

Wyoming Agricultural Statistics Service. *Wyoming Agricultural Statistics.* Wyo. Dept. of Agric., Cheyenne, Wyoming. Annual publication.

Yun, Limei, "Fall Grazing of Trap-Crop Radishes." M.S. Thesis, University of Wyoming, 1997.