IPM Adoption Evaluated: A Strong Foundation for a Safe, Profitable Crop

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Abstract: Impending regulatory actions under the Food Quality Protection Act (FQPA) will have potentially profound impacts on pest management practices in Florida's vegetable industry. Registrations for several key pesticides are likely to be revoked without real-world information on pesticide use. For Florida's tomato growers, the greatest threat from these regulatory actions is the potential loss of the B2 carcinogens, maneb and mancozeb, which are important components of the bacterial post control program. The results of a survey of integrated pest management (IPM) programs in south Florida indicate that bacterial spot is currently the most damaging disease affecting tomatoes, with annual losses averaging 8.6% according to grower estimates. The amounts of these pesticides applied to each grower's crop significantly affected placement on the IPM continuum. IPM programs in south Florida tomatoes (Lycopersicon esculentum Mill.) were surveyed to determine the level of integrated pest management (IPM) used in during the 1997-98 season. Twenty growers participated in this survey, representing 9293 acres in Collier, Dade, Hendry, Lee and Manatee Counties.

Survey results indicate that, despite this dependence on chemical disease control, a wide range of farm management, cultural and sanitation practices are incorporated into a comprehensive control program for this and other pests. The measurement technique incorporated the results of an IPM questionnaire and a review of each respondent's pesticide applications. Questionnaire results indicate that the basic components of IPM, scouting and using thresholds, are nearly universal among tomato growers. The chief biological control agent employed is Bacillus thuringiensis. Most respondents receive scouting reports on beneficial insect activity, and their activity is considered when making spray decisions.

Introduction

Florida vegetable growers face some of the most intense insect and disease pressure in the United States. Their response has been to develop sophisticated integrated pest management (IPM) systems. Interest in measuring the degree of IPM adoption has increased for several reasons. The goal of having 75% of U.S. crops produced under IPM, set by the Clinton Administration sparked an initial wave of interest in IPM measurement. (Swisher, 1995; Funderburk and Chellemi, 1996; Bauske, et al, 1998, Frantz and Mellinger, 1998). The need for real-world information by the implementers of the Food Quality Protection Act (FQPA) on pest problems, pest management techniques and pesticide use has created even greater interest, and is the impetus behind the survey reported here. Beyond uses by regulatory agencies, the results of these surveys will be useful to farmers and IPM practitioners in devising pest management programs that more fully integrate the many practices that are currently available or in

development. Funding for this survey was provided by a grant from the U.S. Department of Agriculture under its Pest Management Alternatives Program.

Materials and Methods

The targeted region for this survey included the area south of Lake Okeechobee. A single Manatee County farm was included, as it was part of a larger operation that included acreage in Collier County. The IPM measurement method used in this survey consisted of three parts: a survey of growers' pest management practices, a review of their pesticide applications for representative fields, and the construction of an IPM continuum.

IPM Survey: To establish points for growers' IPM practices, a questionnaire was prepared which addressed preventive practices for insect, disease and weed management and issues of sound crop production. Each item on the survey was weighted according to its contribution to biologically intensive pest management. Weights ranged from 1 to 8. Respondents provided information on farm size, basic cultural practices, crop production and economics. Respondents were also asked for information on frequently encountered pest problems and estimated losses to those pests. Sample questions and weights are presented in Table 1.

Respondents were asked how frequently or intensively each item was practiced. The possible responses, never, seldom, sometimes, often and always, were assigned values of 0, 0.25, 0.50, 0.75, and 1, respectively. The final point value of each item was obtained by multiplying this weight by the response value.

Pesticide Use Survey: Respondents supplied detailed information about the typical number of applications and typical application rates of each pesticide used for fall and

spring tomato crops. Using these figures and the active ingredient (AI) content of each product, the amount of AI applied per acre was determined for each product.

Pesticide Impact Evaluation: A weighting method was used to adjust pesticide use for the inherent toxicity of active ingredients. Acute toxicity values were determined as the inverse of the LD50. This value was scaled by multiplying by a factor of 100 C.M. Benbrook, personal communication. The active ingredients identified in the pesticide use survey were assigned relative weights reflecting their contribution to the overall mammalian toxicity and risk.

IPM Continuum Score Determination: The IPM Continuum Score for each crop was determined by the method described in Benbrook, et al, 1996. Scores for preventive practices (PPP) identified in the IPM survey were totaled for each of the four portions of the survey, Pre-Plant, Insect Management, Disease Management and Weed Management. Five continuum scores were determined using these PPP's and the weighted pesticide data, generated using the methods described under the pesticide use survey: a Total IPM Continuum Score, a Disease Management IPM Continuum Score, Insect Management IPM Continuum Score, Weed Management IPM Continuum Score and a Soil Health IPM Continuum Score. These scores were calculated by dividing the PPP's by the appropriate mammalian toxicity unit values using the following formulas:

Total IPM Continuum Score = [(Pre-Plant PPP + Insect Management PPP + Disease Management PPP + Weed Management PPP)/(Total Mammalian Toxicity Score / Acre for all groups of AI's)]

Disease IPM Continuum Score = [(Pre-Plant PPP + Disease Management PPP)/(Total Mammalian Toxicity Score / Acre for fungicide AI's)]

Insect Management IPM Continuum Score = [(Pre-Plant PPP + Insect Management PPP)/(Total Mammalian Toxicity Score / Acre for insecticide AI's)]

Weed IPM Continuum Score = [(Pre-Plant PPP + Weed Management PPP)/(Total Mammalian Toxicity Score / Acre for herbicide AI's)]

Soil Health IPM Continuum Score = [(Pre-Plant PPP)/(Total Mammalian Toxicity Score / Acre for fumigant AI's)]

Results and Discussion

Twenty tomato growers participated in this survey, representing 9293 acres of tomato production in Collier, Dade, Lee, Hendry and Manatee Counties. This acreage represents 10.48% of the U.S. fresh market tomato acreage for 1997-98 (Table 2). It also represents 24.78% and 41.64% of state and regional acreage respectively (NASS, 1999, FASS, 1999). Survey respondents' estimates of yields and crop values exceeded state and regional averages by up to 22%. Average farm size was 464.65 acres. The average yield per acre was estimated at 36,827 lb, with an estimated value of $0.396 per lb or $135,577,072.645 for the surveyed acreage.

Typical pest problems experienced by survey respondents are summarized in Tables 3, 4 and 5. The major pest problem is bacterial spot disease, followed by target spot, Fusarium crown and root rot and the silverleaf whitefly, which causes direct plant damage and transmits debilitating virus diseases. Losses to plant diseases, insects and weeds are significant, totaling over 24.59% of potential marketable yield in an average field and having a value of $3,382.03 per acre.

IPM survey results: Survey respondents generally scored well on the IPM preventive practices survey. The overall survey scores ranged from 36.6-66.2 % of the total with an

average of 51.40 % (Table 7). Of the separate pest categories, weed management scores were the lowest (average 29.03%). This was primarily a function of the programmatic nature of weed management in plastic-mulched, staked tomato culture. Weed control programs generally involve several disking passes during the off season. Some fields are allowed to flood naturally during the rainy season, which helps in weed management. However, once beds have been constructed, and the crop has been planted, weed management consists of one or two directed applications of herbicide, usually paraquat dichloride and metribuzin. These applications are generally applied in the first half of the crop, leaving little room for adjusting application intervals. Application rates are also fairly uniform among growers. The weighted survey gave significant weight to these factors of flexibility in application timing and rates, based on pest pressure.

In the cases of pre-plant decisions and insect and disease control, growers generally scored higher, with overall averages of 46.81 %, 56.06 % and 59.35 %, respectively. This variation in scores reflects a combination of the potential range of practices available to growers and the importance placed on different pest complexes.

To view IPM in a different light, the survey questionnaire was also divided into four types of IPM practices, following the classification set forth by the USDA (1998). These consisted of prevention (tillage, crop residue management, etc.), avoidance (adjusting planting dates, crop rotation, etc.), monitoring (scouting, record keeping, soil analysis, etc.) and suppression (pesticide decision making, bio-control, pesticide choice, etc.) Respondent scores according to these categories are presented in Table 8. Growers scored highest in the monitoring 57.51 % and prevention 56.51 %, with suppression slightly lower 49.88 %. Avoidance practices received the lowest scores (36.34 %),

probably due to the difficulty in implementing practices that depend on land use and planting flexibility. Similar results were obtained in the 1996-97 survey (Frantz and Mellinger, 1998) where high land values and market demands drove most grower decisions having to do with filed location, crop selection and crop scheduling.

Pesticide survey results:

Of the pesticide active ingredients listed under FQPA for regulatory action, mancozeb and methomyl were the most widely used in fall plantings or on farms where spring and fall plantings were not reported separately (95.18 % and 43.78 %, respectively). In spring crops mancozeb, methamidophos and methomyl were used on 98.49 %, 40.34 % and 39.98 % of the surveyed acreage at least once, respectively. Other targeted active ingredients included carbaryl, chlorpyrifos, dimethoate, maneb, metam sodium and oxamyl. These compounds were applied to less than 20% of the reported acreage. Of the targeted active ingredients, only mancozeb, maneb and metam sodium were used at or near the total amount per acre allowed by the pesticide labels (see Tables 9 and 10). The fumigants, methyl bromide and chloropicrin were applied to over 99% of all acreage. Notable trends in pesticide use include the use of chlorothalonil for disease control, with over 96% of all acres treated at least once, and the increased use of azoxystrobin with 33-36% of spring and fall acreage, respectively. Despite the widespread use of these alternate fungicides, mancozeb remains the leading fungicide in south Florida tomato crops.

Among insecticides, imidacloprid was applied to over 99% of all acreage. This highly effective silverleaf whitefly control material has allowed some reduction in the use of “hard” pesticides, such as endosulfan, methamidophos and esfenvalerate, which were key

whitefly controls before its introduction. Concurrently with this reduction in "hard" pesticide use for whitefly control, the use of *Bacillus thuringiensis* for control of the armyworm and pinworm complex has increased dramatically. In Tables 9 and 10, different forms of B.t. are reported. The bio-engineered formulations, such as Agree and Mattch, and the B.t. kurstaki subspecies (Dipel, Javelin) were the most widely used. The B.t. aizawi subspecies (Xentari) was less used, probably due to cost factors.

The most widely used herbicides were paraquat dichloride and metribuzin. These herbicides were applied to over 81 % of fall plantings and 92 % of spring plantings at least once.

IPM continuum placement:

The scores from the weighted questionnaire were divided by the acute toxicity adjusted active ingredient load for each farm. Acute toxicity adjustment factors used in this analysis are listed in Table 11. Separate scores for insect, disease weed and soil health management are depicted graphically in Figure 1 and 2 for each farm. Overall IPM continuum scores for all categories are presented in Figures 3 and 4.

Notable among these results are the extremely high scores for Farm ~C, where tomatoes were grown organically. The scores for weed and soil health were set at an arbitrarily high level, because no herbicide or fumigant was applied to these crops. Soil health scores for other respondents were consistent at approximately 100. A notable exception occurred at Farm ~X, where the spring crop was grown on beds fumigated with metam sodium. The LD50 of metam sodium is lower than that of the methyl bromide and chloropicrin combination used on the remaining acreage (Table 11). These differences in continuum placement for this one aspect of tomato IPM illustrate the sensitivity of this

measurement technique to differences in pesticide practices. Such differences are also apparent in insect, disease and weed management scores.

Summary:

Despite severe pest pressure, which annually causes significant economic losses in south Florida tomato crops, growers have adopted IPM to a high degree. The use of the basic components, scouting and thresholds is nearly universal. Growers have adopted many preventive practices, monitoring techniques and sophisticates suppressive methods. High land values and marketing demands have decreased the adoption of such avoidance techniques as field and crop selection and manipulation of planting schedules. However, growers show a willingness to adopt new control practices and materials as they become available or as their efficacy is proven. This scenario bodes well for the future, when regulatory changes under FQPA will limit or remove the use of several important pesticides.

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Table 1. Sample questions from the IPM preventive practices survey with their assigned weights.

How often or intensively would you use the following general integrated pest management practices in a representative field?	Weight
Do you rely on one or more of these sources of crop health information?	
Agrichemical Representative	2.0
Extension Meetings	4.0
Extension Newsletters	3.3
Private Consultant	6.3
Trade Publications	3.6
Other (Please specify): _____	
Do you employ an independent crop consultant for one or more of the following?	
Pre-plant field assessment	4.9
Planting decisions	4.3
Crop nutrition	4.0
Crop scouting	7.3
Record keeping	3.7
Assistance with pest management decisions	6.7
Did knowledge of past pest pressure lead you to decide not to grow tomatoes in any particular fields or parts of fields this year?	5.3
Do you add mycorrhizal organisms to transplant or field soil to mitigate soil-borne diseases?	5.1
Do you destroy volunteer crops and/or crop residues (including cull piles) to limit the threat of future disease problems?	6.6
Do you adjust soil pH as a way to control Fusarium Crown rot?	5.4
Do you adjust Nitrogen sources and ratios as a way to control Fusarium Crown rot?	5.7
Do you clean field equipment when moving from field to field to prevent disease spread?	4.7

How often and by what method do the following personnel scout your fields for insects per planting cycle?

	Frequency of visits per planting	Informal observations	Spot checking historical hotspots	Standardized technical sampling methods
Independent scouts				
Farm personnel				
Agrichemical representative				

Table 2: Acreage planted and harvested, yields and crop value for 1997-98 south Florida tomato crops included in IPM survey.

	Acreage		Yield per acre (lb)	Value per lb	Total Value
	Planted	Harvested			
US Total	88700				
Florida Total	37500	37300	36700	$0.323	$442,431,712.000
Regional Total	22320	22320	31330	$0.364	$254,815,609.580
Included in survey	9293	9293	36827	$0.396	$135,577,072.645
US Total	10.48%				
Florida Total	24.78%	24.91%	100.35%	122.57%	30.64%
Regional Total	41.64%	41.64%	117.55%	108.71%	53.21%
Included in survey	100.00%	100.00%	100.00%	100.00%	100.00%

Table 3. South Florida tomato pests: Frequency of occurrence and type of damage produced.

		Type of damage				
	Frequency of occurrence	Defoliation.	Fruit damage	Reduced fruit set	Plant loss	Loss of vigor
Diseases						
Bacterial Spot	Annual	+	+	+		+
Early Blight	Annual (Winter, Spring)	+	+		+	
Fusarium Crown Rot	Annual (Winter, Spring)				+	+
Late Blight	Sporadic (Winter, Spring)	+	+		+	
Pythium	Annual (Summer, Fall)				+	
Southern Blight	Annual (Summer, Fall)				+	
Target Spot	Annual (Fall)	+	+	+		
Verticillium Wilt	Annual (Winter, Spring)				+	+
Virus Diseases	Annual			+		+
White Mold	Annual (Winter, Spring)				+	+
Insects						
Aphids	Annual (Winter, Spring)					+
Beet Armyworms	Annual (Summer, Fall, Spring)	+	+			
Leafminers	Annual (Winter, Spring)	+				
Silverleaf Whiteflies	Annual		+			+
Southern Armyworms	Annual (Summer, Fall, Spring)	+	+			
Stinkbugs	Annual (Winter, Spring)		+			
Thrips	Annual (Winter, Spring)		+	+		
Tomato Pinworms	Annual (Winter, Spring)	+	+			
Nematodes						
Root Knot Nematode	Annual					+
Weeds						
Eclipta	Annual					+
Goose Grass	Annual					+
Grasses	Annual					+
Nightshade	Annual					+
Nutsedge	Annual					+
Parthenium	Annual					+
Pigweed	Annual					+
Pusley	Annual					+
Ragweed	Annual					+
Sesbania	Spring					+
Smart Weed	Spring					+

Table 4. Pest problems occurring in south Florida tomato crops. Estimates of long-term (5-year) acreage affected and yield losses.

Pest	Acreage where control problems occur	Percent of total acreage	Average grower's estimate of lost potential yield
Diseases			
Bacterial Spot	9030.50	97.18%	8.65%
Early Blight	2488.00	26.77%	1.77%
Fusarium Crown Rot	3687.98	39.69%	2.56%
Late Blight	891.85	9.60%	1.11%
Pythium	402.40	4.33%	0.02%
Southern Blight	555.00	5.97%	0.10%
Target Spot	6448.30	69.39%	3.65%
Verticillium Wilt	137.00	1.47%	0.77%
Virus Diseases	2992.25	32.20%	0.87%
White Mold	33.00	0.36%	0.08%
Insects			
Aphids	1150.00	12.37%	0.06%
Beet Armyworms	3300.00	35.51%	0.31%
Leafminers	8318.00	89.51%	1.02%
Silverleaf Whiteflies	8443.00	90.85%	2.27%
Southern Armyworms	7172.00	77.18%	0.77%
Stinkbugs	560.25	6.03%	0.17%
Thrips	334.00	3.59%	0.02%
Tomato Pinworms	794.68	8.55%	0.08%
Nematodes			
Root Knot Nematode	34.15	0.37%	0.06%
Weeds			
Eclipta	1782.60	19.18%	0.00%
Goose Grass	2200.00	23.67%	0.00%
Grasses	1057.50	11.38%	0.02%
Nightshade	7053.00	75.90%	0.06%
Nutsedge	4559.00	49.06%	0.10%
Parthenium	360.00	3.87%	0.04%
Pigweed	550.00	5.92%	0.00%
Pusley	210.00	2.26%	0.00%
Ragweed	360.00	3.87%	0.04%
Sesbania	1100.00	11.84%	0.00%
Smart Weed	1100.00	11.84%	0.02%
Total % loss per acre			24.59%

Table 5. Estimated economic impact of pest activity in south Florida tomatoes.

Total % loss per acre	24.59%
Average marketable yield per acre from Table 2	36826.92
Potential yield (Avg. yield*(1+Total % loss))	45883.51
Difference (lost yield in lb/A)	(9056.59)
Average gross return per acre from Table 2	$13,752.39
Potential gross return per acre (Avg. gross return*(1+Total % loss))	$17,134.42
Difference (lost return in $/A)	($3,382.03)
Total $$ loss in survey area (lost return*9293 acres)	($31,429,205.38)

Table 6. Frequency of use of selected tomato IPM practices by south Florida tomato growers.

Percentage of respondents using this practice at least half the time				
75-100%				
IPM practice category				
Prevention	Avoidance	Monitoring	Suppression	
X		X		Managing and scouting crop margins
X				Field sanitation (disking)
X				Crop destruction
X				Water table management for disease control
	X			Sanitation for hand laborers
		X		Disease scouting (field and transplants)
		X		Proper disease identification
		X		Maintain written or electronic scouting records
			X	Maintain pesticide application records
			X	Equipment calibration and maintenance
			X	Soil fumigation
			X	Preventive fungicide practices
			X	Pesticides chosen for efficacy rather than cost
			X	Applicator training and licensing
			X	Worker protection standards
			X	Imidacloprid treatments at planting
			X	Adjusting insecticide and fungicide spray intervals according to pest pressure
			X	Protecting transplants from insects and diseases
			X	Resistance management
			X	Choice of biologically friendly pesticides when available
			X	Roguing young plants with disease symptoms
50-75%				
	X			Interrupt sequential plantings
	X			Use resistant varieties
	X			Crop rotation (double cropping)
		X		Scouting for beneficial insects
		X	X	Herbicides chosen based on weed identification
			X	Insecticides and herbicides applied only according to scouting reports
			X	Adjust insecticide and fungicide application rates
			X	Using adjuvants to improve safety and efficacy of applications
			X	B.t. Applied only on demand
			X	Herbicide spot treatments

Percentage of respondents using this practice at least half the time				
25-50%				
IPM practice category				
Prevention	Avoidance	Monitoring	Suppression	
X				Adjusting soil pH and nitrogen sources for Fusarium management
	X			Cleaning field equipment to prevent disease spread
		X		Using tomato pinworm pheromones
			X	Destroy and replant young fields with disease problems
			X	Adjust herbicide application intervals
			X	Spot treatments for diseases
			X	Delaying insecticide applications if beneficial insects are adequate for control
			X	Adjusting herbicide application rates
0-25%				
X				Cover cropping
	X			Field selection based on past pest incidence
	X			Intercropping
	X			Manage planting schedule to avoid pest incidence
	X			Reflective mulch
	X		X	Mycorrhizal seed treatments or amendments to field or transplant soil
		X		Precision agriculture (GPS, grid sampling)
		X		Insect and disease pest mapping
			X	Tomato pinworm mating disruption
			X	Mechanical weed control
			X	Unsprayed refuges for beneficial insects
			X	Rotate herbicides
			X	Beneficial insect releases

Table 7. IPM Survey scores by pest category for south Florida tomato growers.

Farm code	Raw scores					% of total possible points				
	Total points earned	Pre-plant (general)	Insect	Disease	Weed	Total	Pre-plant (general)	Insect	Disease	Weed
Total possible points	815.20	206.86	206.90	295.57	105.87	100.00	100.00	100.00	100.00	100.00
~C	298.47	86.34	73.56	124.13	14.44	36.61	41.74	35.55	42.00	13.64
~G	372.16	88.44	116.55	149.53	17.63	45.65	42.75	56.33	50.59	16.66
~K	354.11	101.46	69.14	154.98	28.53	43.44	49.05	33.42	52.44	26.95
~P	527.30	119.09	131.73	207.62	68.86	64.68	57.57	63.67	70.24	65.04
~Q	426.72	112.26	132.79	163.80	17.87	52.35	54.27	64.18	55.42	16.88
~R	433.19	93.89	144.25	188.57	6.48	53.14	45.39	69.72	63.80	6.12
~S	453.88	118.68	137.46	184.12	13.62	55.68	57.37	66.44	62.29	12.86
~U	445.45	100.49	130.05	173.49	41.43	54.64	48.58	62.86	58.70	39.13
~W	354.36	84.19	79.88	157.92	32.36	43.47	40.70	38.61	53.43	30.57
~X	458.74	92.83	131.20	196.11	38.60	56.27	44.88	63.41	66.35	36.46
~Z	540.10	107.26	159.96	241.85	31.03	66.25	51.85	77.31	81.82	29.31
1A	529.86	97.24	146.11	236.65	49.87	65.00	47.01	70.62	80.06	47.10
1B	366.94	98.44	69.13	172.20	27.18	45.01	47.59	33.41	58.26	25.67
1C	321.34	70.43	84.69	141.08	25.14	39.42	34.05	40.93	47.73	23.75
1E	394.00	121.00	129.46	133.06	10.48	48.33	58.49	62.57	45.02	9.90
DE	467.75	94.81	138.51	205.34	29.09	57.38	45.83	66.95	69.47	27.48
EA	436.02	99.26	135.35	169.70	31.71	53.49	47.98	65.42	57.41	29.95
IO	499.81	98.36	141.34	201.07	59.04	61.31	47.55	68.31	68.03	55.76
OI	376.15	86.99	90.68	157.85	40.63	46.14	42.05	43.83	53.41	38.38
QM	323.22	65.19	77.94	149.38	30.70	39.65	31.52	37.67	50.54	29.00
Average	418.98	96.83	115.99	175.42	30.73	51.40	46.81	56.06	59.35	29.03

Table 8. IPM Survey scores by pest management practice category for south Florida tomato growers.

Farm Code	Raw scores					% of total possible points				
	Total points earned	Prevention	Avoidance	Monitoring	Suppression	Total	Prevention	Avoidance	Monitoring	Suppression
Total Possible Points	815.20	101.52	71.13	200.08	442.47	100.00	100.00	100.00	100.00	100.00
~C	298.47	50.32	11.97	78.09	158.09	36.61	49.57	16.83	39.03	35.73
~G	372.16	47.86	11.70	113.28	199.31	45.65	47.14	16.45	56.62	45.05
~K	354.11	64.50	37.45	68.46	183.71	43.44	63.53	52.65	34.21	41.52
~P	527.30	55.64	42.32	142.53	286.80	64.68	54.81	59.50	71.24	64.82
~Q	426.72	41.14	28.71	125.23	231.63	52.35	40.53	40.37	62.59	52.35
~R	433.19	65.54	14.10	133.44	220.11	53.14	64.55	19.82	66.69	49.75
~S	453.88	57.61	43.29	114.81	238.18	55.68	56.74	60.86	57.38	53.83
~U	445.45	54.24	11.00	149.80	230.41	54.64	53.43	15.46	74.87	52.07
~W	354.36	49.71	30.29	82.91	191.46	43.47	48.96	42.58	41.44	43.27
~X	458.74	55.71	33.14	127.43	242.46	56.27	54.88	46.59	63.69	54.80
~Z	540.10	71.00	34.00	179.14	255.96	66.25	69.93	47.80	89.53	57.85
1A	529.86	67.27	17.52	171.39	273.68	65.00	66.26	24.64	85.66	61.85
1B	366.94	59.39	19.00	122.93	165.62	45.01	58.50	26.71	61.44	37.43
1C	321.34	66.86	19.52	88.91	146.04	39.42	65.85	27.45	44.44	33.01
1E	394.00	44.64	54.69	123.44	171.23	48.33	43.97	76.89	61.69	38.70
DE	467.75	62.80	23.27	116.31	265.37	57.38	61.86	32.72	58.13	59.97
EA	436.02	57.64	16.00	122.38	239.99	53.49	56.78	22.49	61.17	54.24
IO	499.81	62.17	28.80	116.10	292.73	61.31	61.24	40.49	58.03	66.16
OI	376.15	61.75	22.69	64.46	227.25	46.14	60.82	31.90	32.22	51.36
QM	323.22	51.59	17.52	60.42	193.70	39.65	50.81	24.64	30.20	43.78
Average	418.98	57.37	25.85	115.07	220.69	51.40	56.51	36.34	57.51	49.88

Table 9. Pesticide active ingredients applied to fall tomato crops and to tomato farms where no planting break was observed. 1997-98. **Boldface** indicates active ingredients listed under FQPA for regulatory action.

Pesticide type	Active ingredient	Acres treated at least once	% of crop treated at least once	Average lb AI used per treated acre	Average number of applications	Average application rate (lb AI/A)
Fum	Chloropicrin	5954.00	99.58%	38.95	1.00	38.95
Fum	Methyl Bromide	5954.00	99.58%	169.55	1.00	169.55
Fung	Chlorothalonil	5771.00	96.52%	9.62	8.28	1.19
Fung	**Mancozeb**	**5691.00**	**95.18%**	**13.93**	**20.83**	**0.77**
Fung	**Maneb**	**338.00**	**5.65%**	**15.95**	**12.50**	**1.03**
Fung	Benomyl	349.00	5.84%	0.25	1.33	0.17
Fung	Azoxystrobin	2209.75	36.96%	0.22	2.30	0.10
Fung	Bacteriaphage	24.00	0.40%	8.00E+10 [z]	4.00	2.00E+10 [z]
Fung	Copper Ammonium Carbonate	210.00	3.51%	0.20	2.00	0.10
Fung	Copper Hydroxide	5854.00	97.91%	19.54	19.87	1.06
Fung	Copper Oxychloride	275.00	4.60%	7.98	7.00	1.14
Fung	Copper Sulfate	404.00	6.76%	12.99	13.00	0.93
Fung	Fosetyl Al	1273.00	21.29%	3.58	1.50	2.24
Fung	Mefenoxam	3545.00	59.29%	0.14	1.22	0.14
Fung	Propamocarb Hydrochloride	165.00	2.76%	0.78	1.00	0.78
Fung	Sulfur	210.00	3.51%	19.47	7.33	2.47
Herb	Diquat Dibromide	586.00	9.80%	0.38	1.33	0.30
Herb	Glyphosate	1393.00	23.30%	1.25	1.00	1.25
Herb	MCDS	1495.00	25.00%	33.71	1.00	33.71
Herb	Metribuzin	4886.00	81.72%	0.61	1.13	0.54
Herb	Paraquat Dichloride	5732.00	95.87%	0.96	1.53	0.71
Herb	Sethoxydim	118.00	1.97%	0.23	1.00	0.23
Ins/Mit	**Carbaryl**	**125.00**	**2.09%**	**3.00**	**3.00**	**1.00**
Ins/Mit	**Methomyl**	**2617.50**	**43.78%**	**0.74**	**1.65**	**0.50**
Ins/Mit	**Oxamyl**	**600.00**	**10.04%**	**1.50**	**3.00**	**0.50**
Ins/Mit	**Chlorpyrifos**	**1035.00**	**17.31%**	**0.44**	**1.25**	**0.38**
Ins/Mit	**Dimethoate**	**38.00**	**0.64%**	**2.50**	**5.00**	**0.50**
Ins/Mit	**Methamidophos**	**443.15**	**7.41%**	**1.33**	**1.00**	**1.33**
Ins/Mit	Avermectin	3704.00	61.95%	0.01	1.75	0.01
Ins/Mit	Bt aizawi	900.00	15.05%	0.50	6.33	0.09
Ins/Mit	Bt engineered	4610.00	77.10%	1.35	8.38	0.14
Ins/Mit	Bt kurstaki	3526.00	58.97%	0.26	6.64	0.05
Ins/Mit	Crop Oil	1806.00	30.21%	2.05	1.40	1.35
Ins/Mit	Cyfluthrin	521.00	8.71%	0.08	2.50	0.05
Ins/Mit	Cyhalothrin	1832.85	30.65%	0.10	3.50	0.03
Ins/Mit	Cyromazine	2729.00	45.64%	0.16	1.27	0.13
Ins/Mit	Detergent	1375.00	23.00%	1.94	3.50	0.69
Ins/Mit	Endosulfan	1709.00	28.58%	2.37	3.15	0.79
Ins/Mit	Esfenvalerate	909.00	15.20%	0.16	4.60	0.04
Ins/Mit	Garlic/Sugar/ Capsaicin	25.00	0.42%	9.70	2.00	4.85
Ins/Mit	Imidacloprid	5954.00	99.58%	0.29	1.28	0.22
Ins/Mit	Neem oil	7.50	0.13%	8.19	3.00	2.73
Ins/Mit	Permethrin	1144.50	19.14%	0.87	9.50	0.10
Ins/Mit	Piperonyl Butoxide	202.00	3.38%	3.00	12.00	0.25
Ins/Mit	Spinosad	2394.50	40.05%	0.21	1.92	0.09
Nem	Chitin	25.00	0.42%	132.00	1.00	132.00

[z] PFU ()

Table 10. Pesticide active ingredients applied to spring tomato crops. 1997-98. **Boldface** indicates active ingredients listed under FQPA for regulatory action.

Pesticide type	Active ingredient	Acres treated at least once	% of crop treated at least once	Average lb AI used per treated acre	Average number of applications	Average application rate
Fung	Chlorothalonil	3189.00	96.23%	11.13	11.56	0.99
Fung	**Mancozeb**	**3264.00**	**98.49%**	**15.39**	**28.63**	**0.64**
Fung	**Maneb**	**25.00**	**0.75%**	**16.60**	**6.00**	**1.13**
Fung	Benomyl	888.00	26.80%	0.71	2.00	0.29
Fung	Azoxystrobin	1100.00	33.19%	0.35	3.75	0.09
Fung	Bacteriaphage	25.00	0.75%	5.62E+11 [z]	10.00	5.62E+10 [z]
Fung	Copper Hydroxide	3289.00	99.25%	24.37	26.00	1.06
Fung	Copper Sulfate	203.00	6.13%	12.99	13.00	0.93
Fung	Dimethomorph	223.00	6.73%	0.20	1.00	0.20
Fung	Fosetyl Al	425.00	12.82%	5.36	2.00	2.68
Fung	Mefenoxam	2203.00	66.48%	0.15	1.40	0.12
Fung	Propamocarb Hydrochloride	301.75	9.11%	1.42	1.67	0.86
Fung	Sulfur	25.00	0.75%	33.00	15.00	2.20
Fum	**Metam Sodium**	**25.00**	**0.75%**	**95.40**	**1.00**	**95.40**
Fum	Chloropicrin	3289.00	99.25%	28.40	1.00	28.40
Fum	Methyl Bromide	3289.00	99.25%	181.04	1.00	181.04
Herb	Diquat Dibromide	113.00	3.41%	0.38	1.00	0.38
Herb	Glyphosate	400.00	12.07%	1.00	1.00	1.00
Herb	MCDS	1100.00	33.19%	34.88	1.00	34.88
Herb	Metribuzin	3189.00	96.23%	0.47	1.00	0.47
Herb	Paraquat Dichloride	3066.00	92.52%	1.30	1.50	1.00
Herb	Permethrin	316.00	9.54%	1.60	17.00	0.10
Herb	Sethoxydim	101.50	3.06%	0.28	1.00	0.28
Ins/Mit	**Methomyl**	**1325.00**	**39.98%**	**0.68**	**1.67**	**0.38**
Ins/Mit	**Chlorpyrifos**	**200.00**	**6.04%**	**0.50**	**1.00**	**0.50**
Ins/Mit	**Dimethoate**	**25.00**	**0.75%**	**2.50**	**5.00**	**0.50**
Ins/Mit	**Methamidophos**	**1336.75**	**40.34%**	**0.83**	**1.00**	**0.83**
Ins/Mit	Avermectin	2948.00	88.96%	0.02	2.58	0.01
Ins/Mit	BTA	775.00	23.39%	0.46	4.50	0.10
Ins/Mit	BTE	2976.00	89.80%	1.03	7.75	0.14
Ins/Mit	BTK	1814.00	54.74%	0.28	5.63	0.05
Ins/Mit	Crop Oil	1998.00	60.29%	4.05	2.13	1.75
Ins/Mit	Cyhalothrin	1030.05	31.08%	0.08	2.50	0.03
Ins/Mit	Cymoxanil	35.00	1.06%	0.18	2.00	0.09
Ins/Mit	Cyromazine	1566.00	47.25%	0.28	2.20	0.13
Ins/Mit	Detergent	1375.00	41.49%	1.94	3.50	0.69
Ins/Mit	Endosulfan	709.75	21.42%	2.65	3.00	0.90
Ins/Mit	Esfenvalerate	1826.00	55.10%	0.16	4.40	0.04
Ins/Mit	Garlic/Sugar/Capsaicin	25.00	0.75%	9.70	2.00	4.85
Ins/Mit	Imidacloprid	3289.00	99.25%	0.29	1.67	0.19
Ins/Mit	Neem oil	7.50	0.23%	8.19	3.00	2.73
Ins/Mit	Piperonyl Butoxide	203.00	6.13%	4.00	16.00	0.25
Ins/Mit	Spinosad	339.50	10.24%	0.13	1.50	0.09
Ins/Mit	TPW Pheromone	25.00	0.75%	0.04	1.00	0.04
Nem	Chitin	25.00	0.75%	132.00	132.00	132.00

[z] PFU ()

Table 11. Acute toxicity adjustment factors used in determining IPM continuum scores. Incomplete information on some active ingredients resulted in their being left out of this analysis.

Active ingredient	Scaled Inverse LD-50
Avermectin	0.33
Benomyl	0.02
Bt aizawi	0.02
Bt engineered	0.02
Bt kurstaki	0.02
Carbaryl	0.33
Chloropicrin	0.40
Chlorothalonil	0.02
Chlorpyrifos	0.74
Copper Ammonium Carbonate	0.15
Copper Hydroxide	0.10
Copper Oxychloride	0.07
Copper Sulfate	0.33
Crop Oil	0.02
Cyfluthrin	0.40
Cyhalothrin	0.69
Cyromazine	0.03
Diquat Dibromide	0.47
Endosulfan	1.25
Esfenvalerate	1.49
Glyphosate	0.02
Imidacloprid	0.22
Mancozeb	0.02
Maneb	0.02
Mefenoxam	0.20
Methamidophos	3.33
Methomyl	5.88
Methyl Bromide	1.00
Metribuzin	0.05
Neem oil	0.02
Oxamyl	16.67
Paraquat Dichloride	0.67
Permethrin	0.20
Propamocarb Hydrochloride	0.02
Sethoxydim	0.03
Sulfur	0.03

Figure 3. IPM Continuum Scores for South Florida Fall Tomato Crops Based on (1/LD50)*100 Adjustment Factor

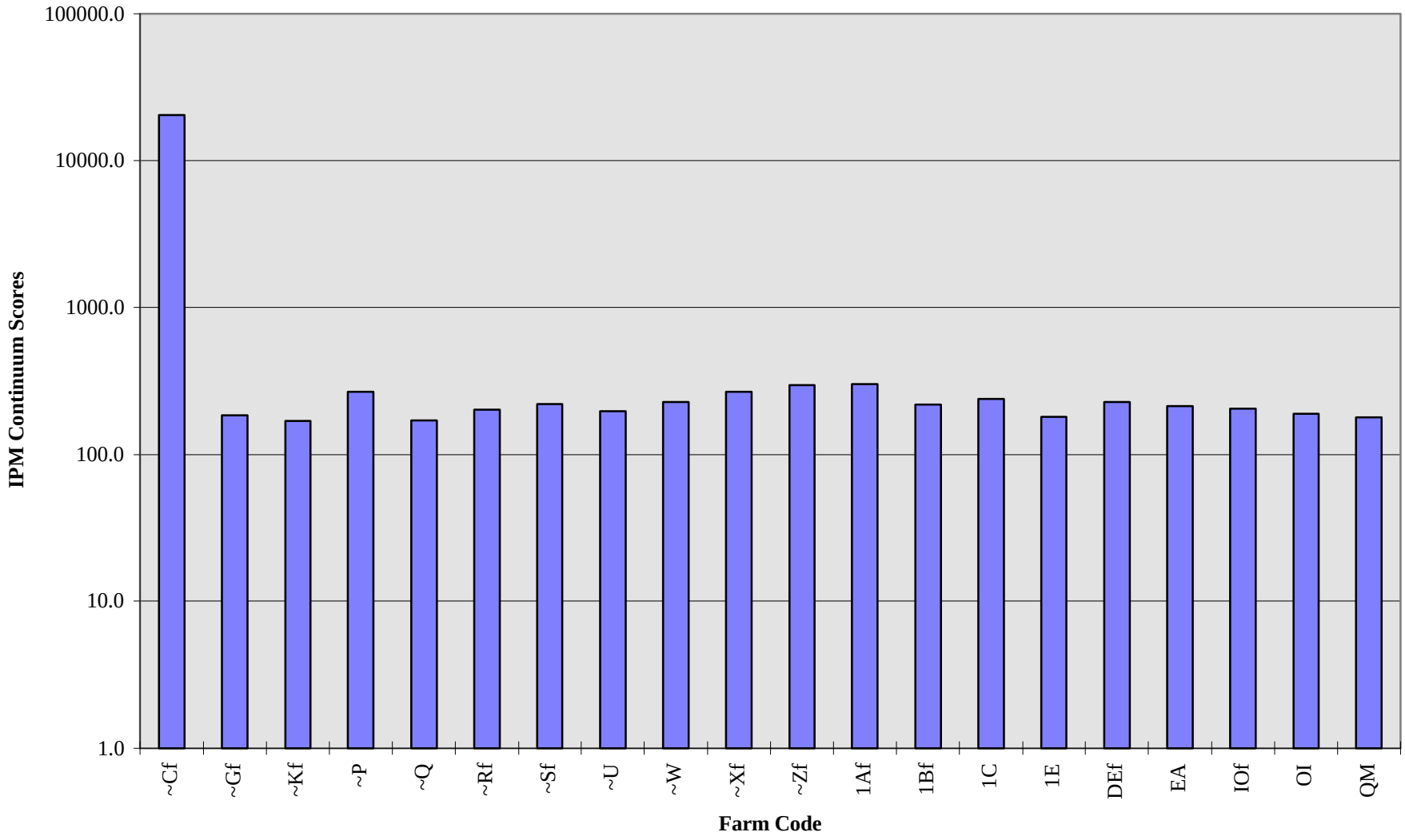

Figure 1. IPM Continuum Scores for South Florida Fall Tomato Crops Using an Adjustment Factor of (1/LD50)*100

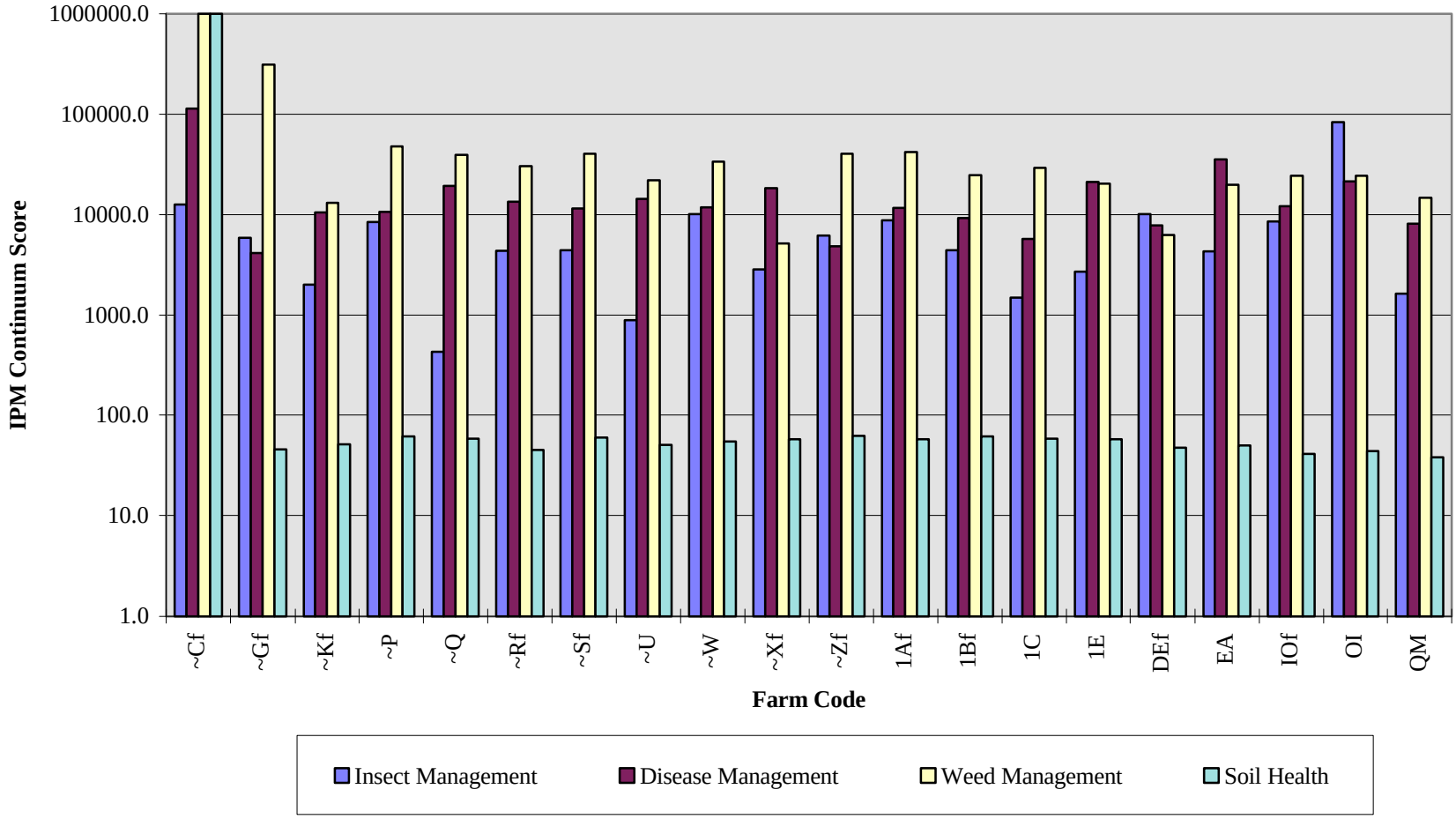

Figure 4. IPM Continuum Scores for South Florida Spring Tomatoes Based on (1/LD50)*100 Adjustment Factor

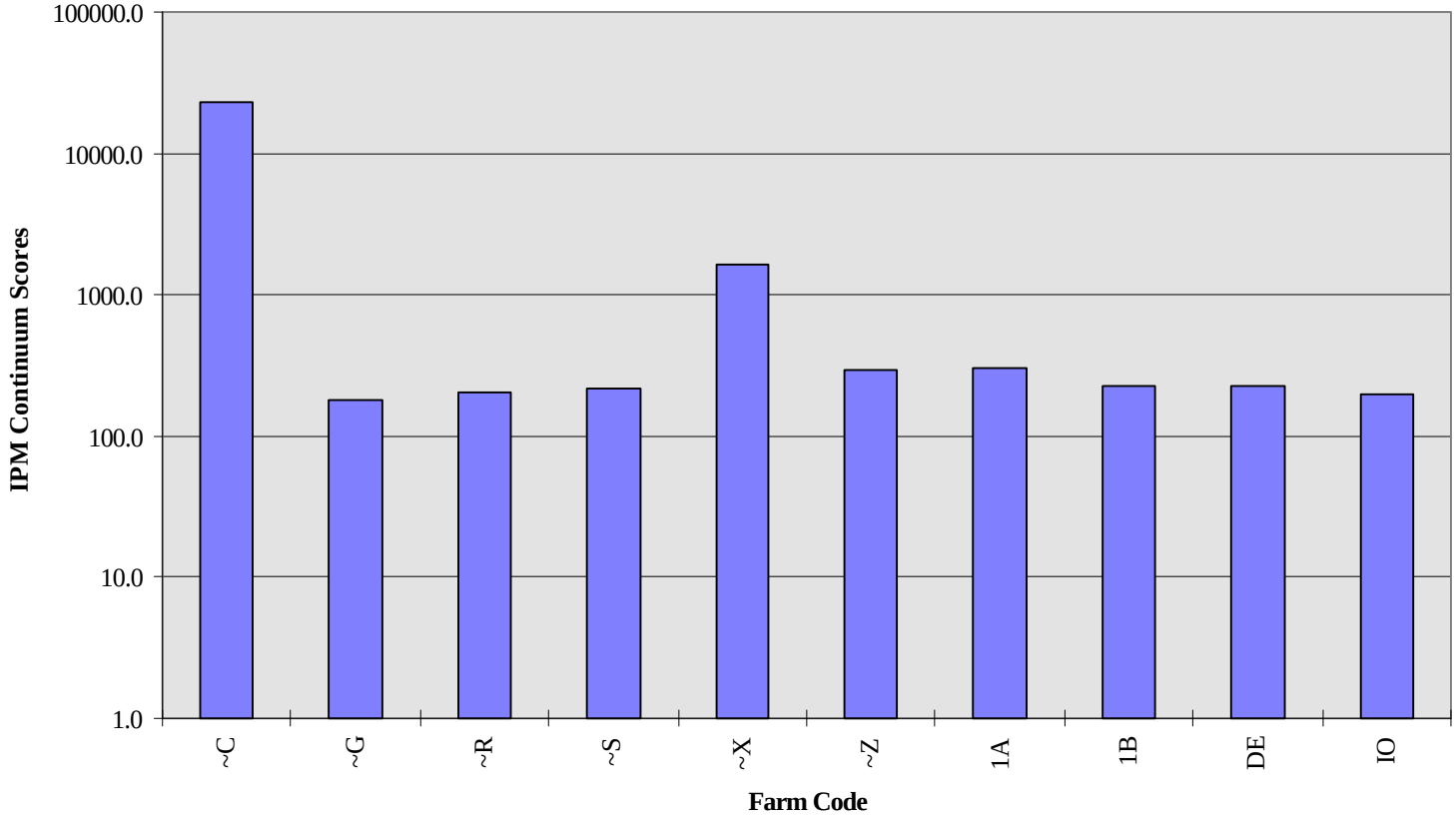
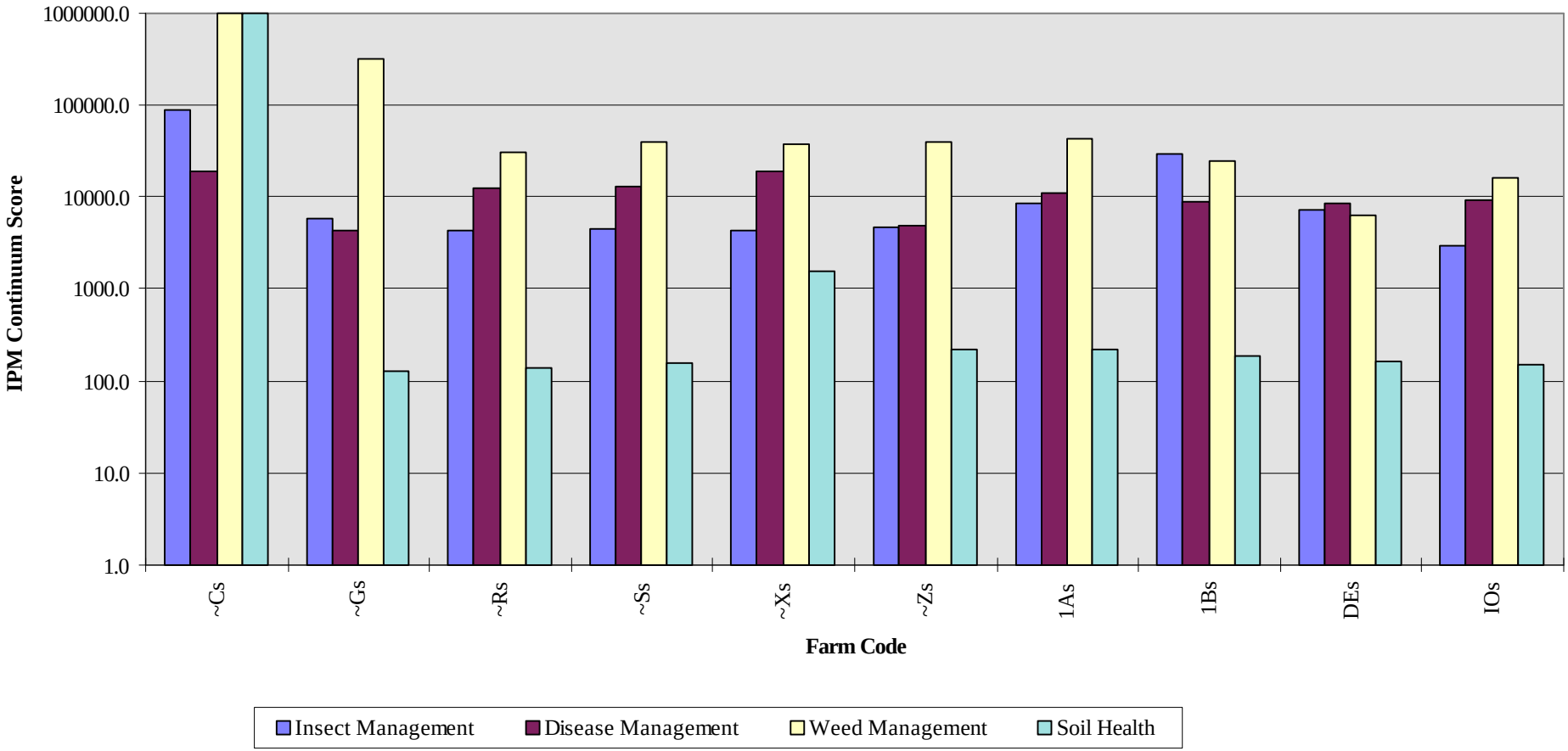
Figure 2. IPM Continuum Scores by Category for South Florida Spring Tomato Crops Using ((1/LD50)*100) Adjustment Factor