Evaluating the Impact of Integrated Pest Management on Agriculture and the Environment in the Texas Panhandle[1]

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ABSTRACT: Agricultural producers in the Texas High Plains are facing the worst comparative economic conditions since 1913. Under these circumstances it is desirable to evaluate which programs are beneficial and which are not. Integrated Pest Management (IPM) is a concept that was introduced in the Texas High Plains in 1976. Over the years many IPM practices have been adopted for the four major crops; corn, cotton, sorghum, and wheat. These practices have been cost or labor saving and have reduced the number and amount of chemical applications. The reduction in production cost is used as a measure of the economic benefit. Contingent valuation is used to estimate the value of the environmental benefit. The IPM practices, which have been adopted, reduce the production cost by more than $173 million per year. In addition these practices have reduced environmental costs, as estimated by contingent valuation, by more than $99 million per year. The total value of the economic and environmental benefit accruing to the Texas High Plains due to the adoption of IPM practices on the four major crops exceeds $272 million per year.

KEY WORDS: value of IPM, environmental benefit, cost savings

Introduction

Agricultural producers in the Texas High Plains are facing the worst comparative economic conditions since 1913. Although nominal prices have remained constant or have increased slightly, real prices are at the lowest level since records are available. Under these circumstances it is desirable to evaluate which programs are beneficial and which should be revised or discarded. Integrated Pest Management (IPM) is a concept that was introduced in the Texas High Plains in 1976. Although IPM systems were not adopted in their entirety, over the past 25 years individual simple innovation have been adopted that when viewed in terms of their compatibility and interaction form an affective system of pest management practices. The four major field crops; corn, cotton, sorghum, and wheat are included in the analysis.

Although numerous authors have addressed the adoption of new technology and the adoption of Integrated Pest Management practices, only a few are referred to in this study (Rogers 1995; Hall and Duncan 1985; Harper, et. al. 1990; and Mullen et. al. 1997).

Comparison of Real and Nominal Prices

Agricultural producers face very high economic pressure. Figure 1 shows nominal and real prices for wheat from 1913 to 2000. In order to best reflect the changes that have occurred during the time period IPM has been a factor, 1972 is selected as the base year. The IPM program was introduced into the Texas Panhandle in 1976. Although nominal prices show a slightly positive trend, real prices exhibit a sharper negative trend. The real value of a bushel of wheat is the lowest it has been in this 87-year period. In real terms the competitive position of the producer in the Texas Panhandle has never been worse.

Comparing the changes in nominal and real prices since 1972 shows the nominal prices increasing and the real prices declining, table 1. The price of corn has increased from $1.57 per bushel to $1.85. However in real terms the purchasing power of a bushel of corn has declined from $1.57 to a low of $0.45 in 1972 dollars. A bushel of corn produced in 2000 will exchange for less than one-third the value it would have exchanged for in 1972. The same pattern is shown for cotton, sorghum, and wheat. These are the four major crops produced in the Texas High Plains

Figure 1. Nominal and Real Prices for Wheat from 1913 to 2000, 1972 Base Year

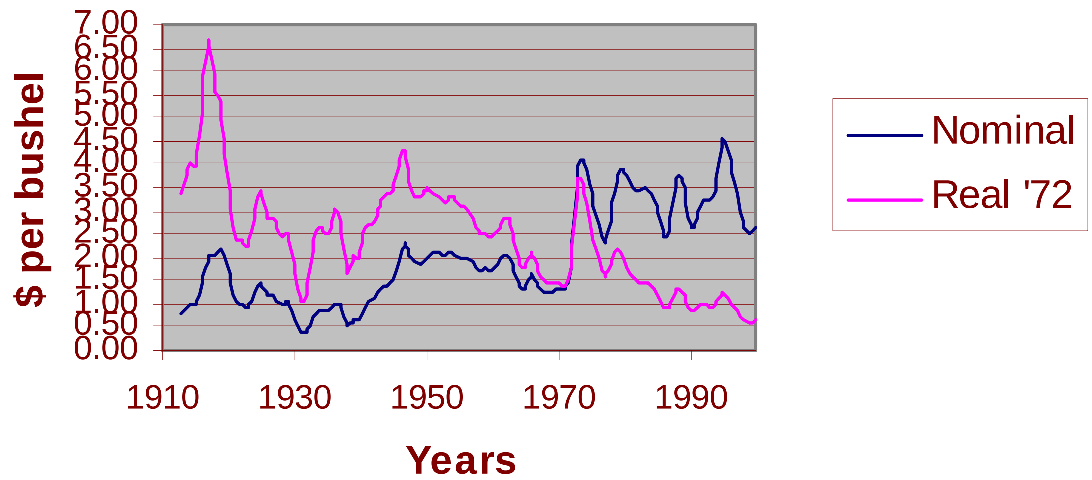

Table 1. Comparison of Nominal and Real Prices for Corn, Cotton, Sorghum and Wheat from 1972 to 2000 and the 2001 Price Required to Match 1972 Buying Power

	Corn		Cotton		Sorghum		Wheat	
Year	Nominal	Real	Nominal	Real	Nominal	Real	Nominal	Real
	$/bu		$/cwt		$/bu		$/bu	
1972	1.57	1.57	27.30	27.30	1.37	1.37	1.76	1.76
1975	2.54	1.97	51.30	39.90	2.36	1.83	3.55	2.76
1980	3.11	1.58	74.70	37.90	2.94	1.79	3.91	1.98
1985	2.23	0.87	56.30	21.90	1.93	0.75	3.08	1.20
1990	2.28	0.73	68.20	21.80	2.12	0.68	2.61	0.83
1995	3.24	0.89	76.50	21.00	3.15	0.86	4.55	1.25
2000	1.85	0.45	57.80	14.00	1.75	0.42	2.65	0.64
2001 Price to match 1972 buying power	**$6.69**		**$116.30**		**$5.83**		**$7.49**	

Projected Costs and Returns for the Four Major Crops in the Texas High Plains

In order to emphasize the importance of pest control expenditure as a component of production costs, pest control has been singled out in the following projected crop budgets, tables 2.a - 2.d. Pest control is shown both in dollar terms and as a percentage of pre-harvest cost. As a percentage of pre-harvest cost, pest control ranges from a low of 8.1% of pre-harvest cost for irrigated wheat to a high of 44.14% of pre-harvest cost for dryland cotton.

Table 2a. 2001 Projected Costs and Returns for Sprinkler Irrigated Corn in the Texas High Plains and the Percentage of Pre Harvest Cost Devoted to Pest Control

	$	% of PHC
Corn for grain – 200 bu.	504.00	
Total Gross Income	**504.00**	
Pest Control	**65.23**	**22.13**
Other Preharvest cost	229.50	
Total Preharvest Cost (PHC)	294.73	
Total Harvest Cost	80.00	
Total Variable Cost	374.73	
Total Fixed Cost	172.63	
Total of All Costs	**547.36**	
Net Projected Returns	**-43.36**	

Adapted from Amosson, Smith, Almas, and Bretz

Table 2b. 2001 Projected Costs and Returns for Sprinkler Irrigated and Dryland Cotton in the Texas High Plains and the Percentage of Pre Harvest Cost Devoted to Pest Control

	Sprinkler irrigated 650 lbs lint		Dryland 275 lbs lint	
	$	% of PHC	$	% of PHC
Cotton Lint	357.80		151.25	
Cottonseed	52.00		22.00	
Total Gross Income	**409.50**		**173.25**	
Pest Control	**77.36**	**28.05**	**76.28**	**44.15**
Other Preharvest cost	198.45		96.51	
Total Preharvest Cost (PHC)	275.81		172.79	
Total Harvest Cost	102.37		45.71	
Total Variable Cost	378.18		218.50	
Total Fixed Cost	171.87		96.41	
Total of All Costs	**550.05**		**314.91**	
Net Projected Returns	**-140.55**		**-141.66**	

Adapted from Amosson, Smith, Almas, and Bretz

Table 2c. 2001 Projected Costs and Returns for Sprinkler Irrigated and Dryland Sorghum in the Texas High Plains and the Percentage of Pre Harvest Cost Devoted to Pest Control

	Sprinkler Irrigated 70 cwt		Dryland 22 cwt	
	$	% of PHC	$	% of PHC
Sorghum for grain	277.20		87.12	
Total Gross Income	**277.20**		**87.12**	
Pest Control	**21.30**	**12.38**	**21.30**	**38.16**
Other Preharvest cost	150.82		34.52	
Total Preharvest Cost (PHC)	172.12		55.82	
Total Harvest Cost	38.50		15.50	
Total Variable Cost	210.62		71.32	
Total Fixed Cost	139.65		37.37	
Total of All Costs	**350.27**		**108.69**	
Net Projected Returns	**-73.07**		**-21.57**	

Adapted from Amosson, Smith, Almas, and Bretz

Table 2d. 2001 Projected Costs and Returns for Sprinkler Irrigated and Dryland Wheat in the Texas High Plains and the Percentage of Pre Harvest Cost Devoted to Pest Control

	Sprinkler Irrigated 65 bu / 120 days		Dryland 18 bu / 105 days	
	$	% of PHC	$	% of PHC
Grazing	48.00		15.75	
Wheat for grain	195.65		54.18	
Total Gross Income	**243.65**		**69.93**	
Pest Control	**13.06**	**8.10**	**6.53**	**22.42**
Other Preharvest cost	148.16		22.60	
Total Preharvest Cost (PHC)	161.22		29.13	
Total Harvest Cost	26.00		14.16	
Total Variable Cost	187.22		43.29	
Total Fixed Cost	118.73		35.30	
Total of All Costs	**305.95**		**78.59**	
Net Projected Returns	**-62.30**		**-8.66**	

Adapted from Amosson, Smith, Almas, and Bretz

The pest control practices for each of the production alternatives are shown in table 3. The per-acre cost and the percentage of pre-harvest cost are also shown. For example, sprinkler irrigated cotton receives one application of herbicide, one hoeing, three applications of insecticides and one seed treatment for a total cost of $77.36 per acre. This represents 28.1% of the pre-harvest cost of producing cotton under sprinkler irrigation.

Table 3. Common Pest Control Activities, Cost per Acre, and Pest Control Expense as a Percentage of Pre Harvest Cost for Sprinkler Irrigated and Dryland Corn, Cotton, Sorghum, and Wheat in the Texas High Plains

	Herbicide	Hoeing	Insecticide	Seed Treatment	Cost ($)	Percent of (PHC)
Corn,sprinkler irrigated	**2**		**1**		**65.23**	**22.1**
Cotton, sprinkler irrigated	**1**	**1**	**3**	**1**	**77.36**	**28.1**
Cotton, dryland	**1**	**1**	**4**	**1**	**76.28**	**44.2**
Sorghum, sprinkler irrigated	**1**		**0.33**		**21.30**	**12.4**
Sorghum, dryland	**1**		**0.33**		**21.30**	**38.2**
Wheat, sprinkler irrigated			**1**		**13.06**	**8.1**
Wheat, dryland			**0.5**		**6.53**	**22.4**

<u>Integrated Pest Management (IPM)</u>

The concept of Integrated Pest management (IPM) was introduced in the late 1960s and early 1970s. The initial emphasis was on the implementation of a complex set of practices that would be adopted by producers. This set of primarily cultural, biological and genetic practices were to eliminate the use of chemical pesticides. The initial focus of the IPM program was biological. It focused on the crop and the control of pests. The elimination of pest populations was the goal. Rogers has shown that complex innovations that are very different from current practices are less likely to be adopted than simple innovations that are easily perceived as compatible with current practices.

The focus of IPM has shifted to economic. The goal has become to select techniques that will keep the pest populations at low, non-economic, levels and utilize chemical applications only after economic thresholds have been reached. The focus has shifted from biological to economic. The selection of methods has evolved from deterministic to optimization.

Integrated Pest Management (IPM) is defined as the use of multiple tactics in a compatible manner to maintain pest populations at levels below those causing economic injury while providing protection against hazards to humans, domestic animal, plants, and the environment, (Arneson 2000). The goal of IPM is to optimize pest control in relation to the total plant production system in the light of economic, social, and environmental conditions. Tactics used in IPM can be categorized as chemical, biological, cultural, physical, genetic, and regulatory procedures.

Economic thresholds are becoming more important in determining the application of chemical control measures. The most useful definition of economic threshold is attributed by Pedigo to Thompson and White. They define economic threshold as "that point at which the incremental cost of pest control is equal to the incremental return resulting from pest control." This describes the economic concept of selecting the profit maximizing level of a resource. It establishes the condition where Marginal Factor Cost is equal to Marginal Value Product. Economic thresholds can be expressed as simple a rule of thumb, a range of pest populations related to the age and development of the plant, or a more complex relationship indicating pest density as a function of the price of the product and the cost of applying the control measure.

Production of the Four Major Crops in the Texas High Plains, 1999

Corn, cotton, sorghum, and wheat are the four principle crops produced in the Texas High Plains. In 1999 these crops accounted for 5.84 million acres harvested and produced a market value of $1.83 billion. The breakdown by crop and irrigated or dryland production practice is shown in table 4.

Table 4. 1999 Acres Produced, Total Production, Yield per Acre, Value of Production, and Value per Acre for Irrigated and Dryland Corn, Cotton, Sorghum, and Wheat in the Texas High Plains

	Acres Planted 1000's	Acres Harvested 1000's	Production	Yield per Acre	Value $ million	Value per Acre $
Corn			1000 bu	bu./a		
Total	887.0	800.0	142,342	177.9	320.270	400.34
Irrigated	876.0	790.5	141,936	179.6	319.356	403.99
Dryland	11.0	9.5	406	42.7	0.914	96.16
Cotton			1000 lbs.	lbs./a		
Total	3,820.0	2,328.0	3,006,000	1291.2	1,244.484	534.57
Irrigated	1,964.0	1,120.0	2,132,000	1903.6	882.648	788.08
Dryland	1,856.0	1,262.0	874,000	692.6	361.836	286.72
Sorghum			1000 cwt	cwt/a		
Total	1,194.0	1,120.0	34,110	30.5	104.036	92.89
Irrigated	456.0	438.0	17,785	40.6	54.244	123.85
Dryland	738.0	682.0	16,325	23.9	49.791	73.01
Wheat			1000 bu	bu./a		
Total	2,515.0	1,596.0	67,676	26.9	159.039	63.24
Irrigated	773.0	483.0	29,524	38.2	69.381	89.76
Dryland	1,742.0	1,115.0	38,152	21.9	89.657	51.47
Total	**8,416.0**	**5,844.0**			**1,827.828**	**312.77**

Adoption of IPM Practices (Diffusion of Innovation)

Rogers has studied the adoption of technology and the diffusion of innovation through a society or culture. He states that the adoption of an innovation will be affected by the attributes of the innovation. The attributes of the innovation that most affect adoption are relative advantage, compatibility, complexity, trialability, and observability.

Early promotions of IPM programs were as complex systems of interacting practices. Producers tended to reject adoption of these systems because they were perceived as too complex and not compatible with existing production practices. Over time producers did adopt individual practices that demonstrated a relative advantage by controlling pests at reduced cost or reduced labor. The practices were simple, compatible with existing methods, and had been observed on extension field days and demonstrations. These practices included cultural practices for corn, sorghum and wheat, Bt corn and cotton varieties, greenbug resistant sorghum varieties, and Roundup Ready corn and cotton varieties (Cronholm 2001; Patrick 2001; and Bean 2001). Although not adopted as a set, the adoption of compatible simple innovations that complement and interact with each other has accomplished the same desired goal.

Insecticide Use and Environment Cost as measured by Contingent Valuation

Identifying pesticide risk is essential for valuing the environmental benefits of an IPM program. Total pounds of active ingredients is only one factor in establishing environmental risk. The toxicity, mobility and persistence of the pesticide and the component of the environment affected are also important. Higley and Wintersteen identify eight broad components of the environment; acute human, chronic human, groundwater, surface water, aquatic species, avian species, mammalian species, and non-target arthropods. They also established three levels of environmental risk, high risk, moderate risk, or low risk. One of these three risk rating is assigned for each of the eight environmental components for each pesticide. These ratings are shown in table 6 for the most commonly used pesticides in the Texas High Plains.

These ratings are converted into economic values by applying contingent valuation values that reflect the willingness to pay to reduce environmental risk to the risk ratings. Mullen, et. al. developed the values for risk reduction in the eight environmental components and three risk levels from a survey of 3000 individuals drawn randomly from motor vehicle registration records and local telephone directories throughout the United States, table 5. These values are combined with the risk ratings to estimate values for the commonly used pesticides. The assumption is made that since the value represents the consumer's willingness to pay for environmental risk reduction it also represents the benefit accruing to the consumer from a reduction of one application of the pesticide. Therefore when IPM practices result in the reduction of one chemical application the environmental cost is reduced by an amount that is equal to the consumer's willingness to pay for the accompanying reduction in environmental risk. These values are reported in table 6 for the most commonly used pesticides in the Texas High Plains.

Table 5. Willingness to Pay to Reduce High, Medium, and Low Environment Risks in Eight Environmental Risk Categories as Determined by Contingent Valuation Survey

	High Risk		Moderate Risk		Low Risk	
Environmental Category	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
Acute Human	5.25	0.28	3.55	0.21	2.14	0.17
Chronic Human	5.63	0.29	3.85	0.23	2.32	0.18
Groundwater	5.60	0.29	3.78	0.22	2.28	0.18
Surface Water	5.40	0.28	3.60	0.21	2.16	0.17
Aquatic Species	5.36	0.28	3.53	0.21	2.15	0.17
Avian species	5.09	0.28	3.34	0.20	2.00	0.17
Mammalian Species	5.07	0.27	3.33	0.20	2.03	0.17
Arthropods	4.61	0.27	3.06	0.20	1.84	0.16

2000 Dollars Source: Mullen, Norton, and Reaves

IPM Practices Adopted by Producers of the four Major Crops in the Texas Highplains

IPM tactics fall into the categories of chemical, biological, cultural, physical, genetic, and regulatory procedures. Combinations of tactics from different categories are utilized to give the best control of the crop pests. IPM practices common in corn production in the Texas Panhandle include cultural, biological, chemical and biotech (transgenics). The cultural practices include crop rotation, fall sweeping corn ground, early harvest, and corn saver equipment on the combine head that will effectively harvest corn that has 30% to 50% lodged plants. Biological control is promoted by practices that conserve and enhance natural predators and parasites. Chemical applications are used only after pest populations have exceeded economic thresholds. Biotech practices include Bt (Bacillus thuringiensis) varieties and Roundup Ready varieties.

The combination of the cultural practices, the encouragement of biological control agents and the planting of Bt varieties eliminate the need for spraying on the treated acres. In the Southern Panhandle the use of Bt hybrids is limited to 50% of the planted acres. The saving from the reduction of in one spray application on 50% of 50,000 acres of corn is $0.375 million in production cost and $0.313 million in environmental cost. In the Northern Panhandle the use of Bt hybrids is restricted to 80% of the planted acres. The savings from the reduction of one spray application on 80% of 837,000 acres amounts to $10.037 million in reduced production cost and $8.39 million in reduced environmental cost, table 7.

IPM tactics applied to cotton production include cultural, biological, chemical, biotech, and regulatory. Primary cultural practices involve scheduling planting time so that the plants get quick germination and rapid growth, and the plants have minimum exposure to pests. Biological practices focus on the conservation and enhancement of natural control agents. Chemical applications are determined by monitoring the pest populations and applying chemicals only after pest populations reach economic thresholds. Biotech (transgenic) practices include

Roundup Ready varieties. The establishment of a boll weevil eradication program is the primary regulatory measure.

Table 6. Risk Rating for each Risk Category, Environmental Cost, and Production Cost for One Application of Some Commonly Used Insecticides in the Texas High Plains

Insecticide	Risk Category								Environmental cost	Production Cost of One Application
	1	2	3	4	5	6	7	8	($/A)	($/A)
aldicarb (Temik)	**HR**	**LR**	**HR**	**LR**	**HR**	**HR**	**HR**	**HR**	**10.76**	**9.65**
azinphos-methyl (Guthion)	**LR**	**HR**	**HR**	**MR**	**HR**	**HR**	**HR**	**HR**	**11.12**	**7.94**
Bt	**LR**	**NR**	**NR**	**LR**	**LR**	**NR**	**NR**	**NR**	**2.25**	**19.09**
carbofuran (Furadan)	**HR**	**LR**	**HR**	**LR**	**HR**	**HR**	**HR**	**HR**	**10.76**	**22.54**
chlorpyrifes (Lorsban)	**LR**	**HR**	**MR**	**MR**	**HR**	**HR**	**HR**	**HR**	**10.18**	**18.52**
Dimethoate	**MR**	**LR**	**LR**	**MR**	**HR**	**HR**	**LR**	**MR**	**8.53**	**8.44**
Malathion	**LR**	**LR**	**LR**	**LR**	**MR**	**LR**	**LR**	**LR**	**6.14**	**5.94**
methyl parathion	**LR**	**LR**	**LR**	**MR**	**MR**	**LR**	**LR**	**MR**	**8.51**	**11.86**
Permethrin	**LR**	**HR**	**LR**	**LR**	**HR**	**LR**	**LR**	**HR**	**8.25**	**11.97**

Table 7. Estimate of production and environmental cost reduction and total saving due to the adoption of IPM practices in the Texas Highplains.

Crop	Reduction in Production Cost	Reduction in Environmental Cost	Total Savings
	$ million	$ million	$ million
Corn	10.412	8.703	**19.115**
Cotton	114.142	61.731	**175.873**
Sorghum	24.513	12.501	**37.014**
Wheat	24.365	16.659	**41.024**
Total	**173.432**	**99.594**	**273.026**

The combining of these IPM practices reduces chemical application from 3 to 4 per year down to 1 to 2 per year. Savings from the reduction in two spray applications on 3,820,000 acres include a reduction of $114.142 million in production costs and a reduction of $61.731 in environmental cost, table 7. Bt cotton varieties have not been widely adopted due to the acreage license fee. The license fee to plant Bt varieties is $30 per acre while the average cost of the chemical application replaced is only $11 per acre.

IPM tactics applied to grain sorghum include cultural, biological, chemical and genetic. Cultural practices include crop rotation and planting date. Biological practices involve the conservation and enhancement of natural control agents. The application of chemicals is determined by the utilization of economic thresholds on pest populations rather than a spray schedule. The primary genetic practice is the development of biotype c, d, e, i, and k greenbug resistant varieties.

The interaction of the cultural and biological practices with the planting of greenbug resistant varieties eliminates the need for a regular spray schedule. The saving from the elimination of one spray application on 1,194,000 acres includes $24.513 million in reduced production costs and $12.501 million in reduced environmental costs, table 7.

IPM tactics applied on winter wheat include cultural, biological and chemical practices. Cultural practices include cultivation to destroy volunteer wheat from the preceding crop, delayed planting time to reduce the probability of pest carry over from one crop to another and grazing the wheat during the winter. Biological practices focus on conserving and enhancing the population of natural pests and parasites.

The combination of the cultural practices and the conservation of natural predators maintain pest populations below the economic threshold over 80% of the time. The elimination of one spray application on 80% of 2,515,000 acres results in savings of $24.365 million in production costs and $16.659 million in environmental costs.

Summary

IPM practices have been promoted in the Texas Panhandle since 1976. During that time period the production of the four major crops; corn, cotton, sorghum and wheat has increased dramatically. On the other hand the competitiveness of the crops has decreased. Real commodity prices have declined by more than two-thirds between 1972 and 2000. Even considering nominal prices, all four of the major crops are projected to show losses in 2001. Projected losses range from $8.66 per acre for dryland wheat to a high of $141.66 for dryland cotton.

The bleak economic outlook would be even worse without the cost saving accruing from the adoption of IPM practices that have reduced the need to apply pesticide sprays. The commonly adopted IPM practices reduce the production cost by more than $173 million per year. In addition environmental quality has benefited. The adoption of these practices has reduced environmental costs, as estimated by contingent valuation, by more than $99 million per year. The total value of the economic and environmental benefit accruing to the Texas High Plains due to the adoption of IPM practices on the four major crops exceeds $272 million per year.

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