

Producer Adoption of Pecan IPM in Texas

Bill Ree¹, Alexandra Gomezplata² and Marvin Harris^{3,4}

Abstract. The process of developing new knowledge, incorporating that knowledge into a functional program and delivering it to stakeholders, and evaluation of the success of the program is discussed in the context of the Texas Pecan integrated pest management (IPM) program conducted through the Texas A&M University System. The Texas Pecan IPM Program has developed strategies and tactics through research that have been effectively communicated to producers resulting in significant behavioral changes in management practices. During the past 25 years, Texas pecan producers have reduced insecticide and fungicide sprays and timed them more precisely, thereby, reducing risks of losses associated with pest resistance, while conserving natural enemies, and minimizing adverse impacts on the applicator, the consumer and the environment. The overall reduction in pesticide is estimated currently to be 192,000 kg/yr less than was used in 1980 with a material cost savings to producers of \$4.4 million/yr in Texas. The consumer benefits from the healthier economy and environment resulting from this program.

Introduction

The application of science to serve human needs derives from a research base that formalizes principles demonstrating feasibility that are then implemented by affected practitioners. Feasibility is usually demonstrated to a narrow audience of scientists, typically through refereed journal publications, and implementation is usually conducted by the lay public, following an often complex and ongoing vetting process in the public arena. The Land Grant University System (LGS) is well suited to develop, deliver and evaluate such programs because it generates and coordinates education, research and outreach activities among stakeholders in the public and private sectors (Harris and Hamman 1989; Table 1). The LGS is a clearinghouse that focuses stakeholders interests in science and agriculture to resolving problems faced in society. The LGS is unique to the United States and provides a contiguous inter-agency path from the generation of an idea to a change in human behavior that benefits society (Harris 2000, 2001). These changes are incrementally achieved and collectively garner huge benefits to be justifiably and largely enjoyed by the society whose taxes provided substantial support to such endeavors. One such example is provided by the Integrated Pest Management (IPM) Pecan Program in Texas.

¹ Extension Program Specialist II, District 10

² Formerly, Master of Agriculture student

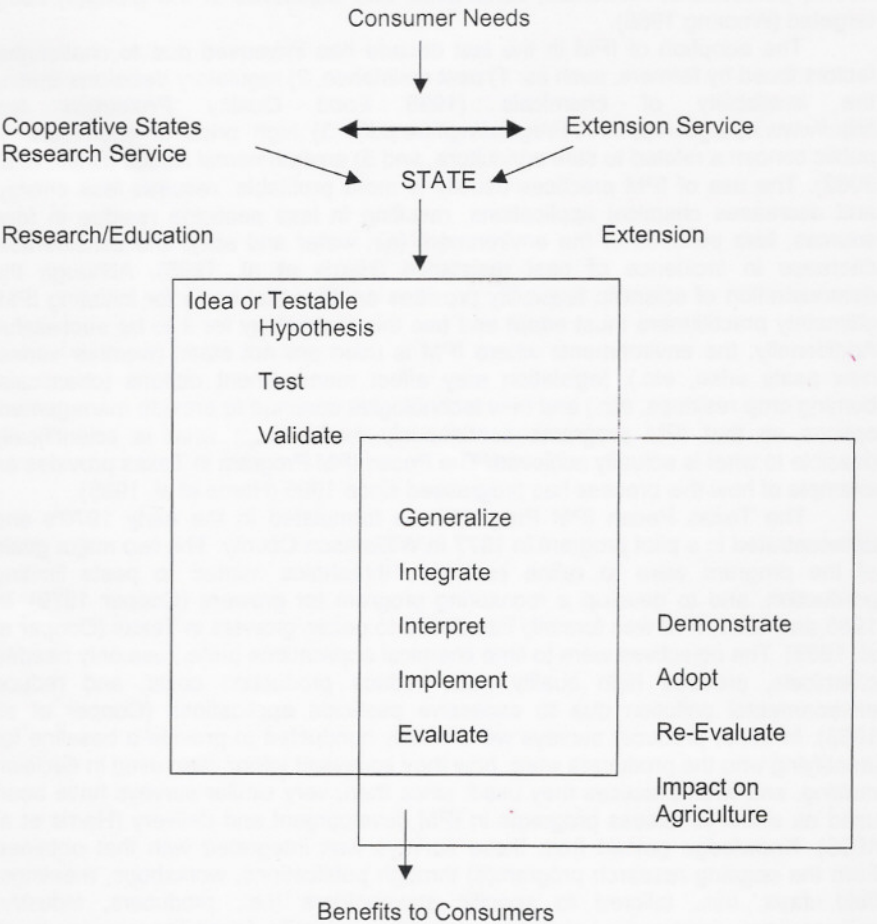
³ Professor of Entomology, Department of Entomology, Texas A&M University, College Station, TX 77843-2475 USA

⁴ Corresponding author; e-mail: m-harris@tamu.edu

Table 1. Schematic of the manner in which new knowledge impacts agricultural production and benefits the consumer in the Land Grant University System in the United States (Modified from Harris and Hamman 1989).

General Objective: To reliably produce cheaper, more abundant, high quality food and fiber, at less cost with minimum adverse effects on the environment.

Specific Objective: Participate in one or more phases of the education process and maintain a commitment to the general objective.



IPM originated in the LGS in the 1950's and adoption by various practitioners to various degrees has occurred (Benbrook et al. 1996, Kogan 1998). IPM was initially catalyzed by President Nixon (1972), who encouraged development and adoption of the concept aided by legislative action (US Senate 1971); this was later

legislation, including the Food Quality Protection Act of 1996 (see <http://www.epa.gov/oppfead1/fqpa/backgrnd.htm>). IPM is a sustainable and ecological approach to managing pests by combining practical methods of pest control including biological, cultural, physical, legislative and chemical methods, to obtain high production in the most economic way with minimal environmental disruption (Vanderman et al. 1994). IPM focuses on tactics that will prevent or avoid anticipated pest problems instead of remediating problems once they occur. Demonstrating the feasibility of IPM to the scientific community remains an ongoing process through refereed journal publications that integrates into agendas of other stakeholders via trade journals, newsletters and education programs so that success is obtained one convert at a time by understanding and addressing the needs, perceptions, resources, constraints, and objectives of the group(s) being targeted (Wearing 1988).

The adoption of IPM in the last decade has increased due to challenging factors faced by farmers, such as: 1) pest resistance, 2) regulatory decisions limiting the availability of chemicals (1996 Food Quality Protection Act, <http://www.epa.gov/opp00001/regulating/fifra.pdf>), 3) high price of chemicals, 4) public concerns related to safe agriculture, and 5) environmental issues (Smith et al. 2002). The use of IPM practices usually is more profitable, requires less energy, and decreases chemical applications, resulting in less pesticide residue in food sources, less pollution of the environment (air, water and soil), and considerable decrease in incidence of pest resistance (Harris et al. 1998). Although the demonstration of scientific feasibility provides an essential basis for initiating IPM, ultimately practitioners must adopt and use this technology for it to be successful. Additionally, the environments where IPM is used are not static (weather varies, new pests arise, etc.), legislation may affect management options (chemicals, burning crop residues, etc.) and new technologies continue to provide management options so that IPM programs continuously evolve from what is scientifically possible to what is actually achieved. The Pecan IPM Program in Texas provides an example of how this process has progressed since 1996 (Harris et al. 1998).

The Texas Pecan IPM Program was formulated in the early 1970's and demonstrated in a pilot program in 1977 in Williamson County. The two major goals of the program were to refine economic thresholds related to pests limiting production, and to develop a monitoring program for growers (Cooper 1979). In 1980 and 1981, IPM was formally introduced to pecan growers in Texas (Cooper et al. 1983). The objectives were to time chemical applications better, use only needed chemicals, produce high quality nuts, reduce production costs, and reduce environmental pollution due to excessive pesticide applications (Cooper et al. 1983). In 1980, producer surveys were initially conducted to provide a baseline for identifying who the producers were, how they accessed information used in decision making, and what practices they used; since then, very similar surveys have been used as a tool to assess programs in IPM development and delivery (Harris et al. 1998). Knowledge gained from these surveys was integrated with that obtained from the ongoing research program(s) through publications, workshops, meetings, field days, etc., tailored to specific stakeholders (i.e., producers, industry, policymakers, consumers, etc.) to ensure that scientific feasibility was rendered relevant to the user groups to aid adoption (Harris et al. 1998). Although we recognize the view held by many that persuading farmers to adopt IPM has always been difficult despite the known economic and environmental benefits (Corbet 1981, Grieshop et al. 1988, Wearing 1988), we contend that such shortcomings arise not from deliberately ignoring sound information but from reasoned judgments based

upon existing information that tempers the rate and degree of IPM adoption by user groups through time.

We endeavor in this paper to show linkages among stakeholders; they begin with demonstrating scientific feasibility and continue through program development by outreach activities, adoption by producers and ultimately impacting the society at large. The pecan research community consists primarily of horticulturists, entomologists and plant pathologists dedicating 50% time or more to the commodity in LGS or USDA positions along with other scientific disciplines. The major pecan research working groups are the formal Southern Regional Project (established in the early 1970's as S-88 and renewed [now S-1017] at ca. 5 yr intervals up to the present, meeting annually emphasizing research on pecan insects under CSREES sponsorship), and the more informal multi-disciplinary and multi-agency National Pecan Research and Extension Workers Forum that gathers periodically to discuss and sometimes publish proceedings of their work. The USDA Pecan Breeding and Genetics Research Unit (Snook, TX) is also a major source of pecan research. Pecan Extension is embedded in LGS institutions and typically interfaces with pecan research working groups for program development. Producer organizations occur in most pecan growing states and include the Texas Pecan Growers Association (publisher of Pecan South) and the Western Pecan Growers Association that directly relate to Texas producers. Industries serving the pecan market work with scientists and producers through the above organizations or their equivalents as well as directly with individuals. Major governmental organizations that affect the Texas pecan industry include the Environmental Protection Agency and the Texas Department of Agriculture. These people and organizations are the principal stakeholders and provide the context for development, delivery and adoption of the Texas Pecan IPM Program.

Evaluation of the Texas Pecan IPM Program (since 1996) requires examination of: 1) progress in research, 2) integration/delivery to producers, 3) assessment of the degree of adoption, and, 4) calculations of impact.

Research and Extension Factors. The pecan nut casebearer, *Acrobasis nuxvorella* Neunzig (Lepidoptera: Pyralidae), is a key pecan pest whose management was aided by discovery of a sex pheromone (Millar et al. 1996) that could be used in conjunction with an established economic threshold and sequential sampling plan (Harris et al. 1998). Newly labeled chemicals, most notably tebufenozide for management of lepidopterous larvae, became available and were shown to be effective in treating otherwise damaging densities of pecan nut casebearer and hickory shuckworm, *Cydia caryana* Fitch (Lepidoptera: Tortricidae). The World-Wide Web expanded, personal computer use increased and integration of the existing paper based information program into other electronic formats (CD-ROM, Web Page, e-mail, etc.) began. Passage of the Food Quality Protection Act of 1996 identified "at-risk" chemicals that included organophosphates and carbamates, which are heavily relied upon for management of key pests in the context of the Texas Pecan IPM Program (Harris et al. 1998). It was anticipated that many of these chemicals may cease to be available to the pecan industry; thus spurring a re-evaluation of existing alternative chemistry and evaluation of new methods and materials for integration into IPM Programs. The development and delivery of the Texas Pecan IPM program to stakeholders continued with efforts to communicate the evolving program and program elements to both new and existing producers and others to allow increased adoption. We note that this is a dynamic environment.

Pecans are grown in more counties in Texas than any other commercial crop. Nuts can be harvested and sold to accumulators from 1) wild trees, 2) semi-domesticated trees typical of cow-pecan ranching where competing trees and brush

have been removed and understories replaced by grass for grazing, and 3) vegetatively propagated trees. Size of operations varies from a few trees to improved orchards comprising hundreds of hectares. New producers begin operations and established producers change operations. Chemicals and industries come and go and continually strive to develop the pecan market. New legislation affects the industry. Support infrastructure personnel from TAMUS (Texas A&M University System) (i.e., IPM Specialists, County Agents), other agencies, Texas Pecan Growers Association, producer cooperators, etc., come and go. Technological changes continue with uneven rates of adoption throughout the industry. The LGS itself is also challenged to fulfill its mandate to educate and inform the public on food, fiber, fuel and health issues with dwindling resources and increasing responsibilities; however, this is beyond the scope of this paper. The major point here is that the Texas Pecan IPM Program is not a static recipe, but an evolving repast that continually adapts to educate, integrate and re-educate stakeholders. Progress is primarily achieved by changing human behavior.

Past surveys of Texas pecan producers show that direct use is not made of the refereed journal literature (Harris 1998). Information is obtained through personal contacts, meetings, field days, workshops, short courses, and producer oriented publications. Activities conducted from 1997-2005, by the Pecan IPM Specialist (Bill Ree) assigned to transfer information to Texas producers, included presentations at 157 county field days, 20 State pecan producer annual meetings, 144 news articles, and 53 newsletters, reaching estimated total audiences of: 4,610; 7,300; 90,000; and 6,450, respectively. The Texas A&M Pecan Insect Lab (Marvin Harris and graduate students) made presentations at 14 pecan producer annual meetings reaching a total audience of 6,000 people (note that the information was targeting several thousand Texas pecan producers over a 9-year period, which results in individual producers being reached multiple times). There were 12 papers published in Pecan South and four in the Pecan Grower during the period, with each paper reaching an audience of 5,000. There were about 200 cooperative research trials conducted with producers and 500 field visits made by project personnel during the period. A web-site, <http://pecankernel.tamu.edu/>, was also initiated during the period. Additionally, hundreds of e-mails, telephone calls and letters regarding the program were received and made during the period with producers. These constitute the principal activities resulting in a targeted contact of Texas pecan producers during the period.

Program assessment was aided by use of a questionnaire. The questionnaire was administered through a mailing list provided by the Texas Pecan Growers Association (TPGA) and sent to 564 addressees on Dec. 16, 2003.

Results and Discussion

We received 196 usable surveys from all areas of the state, from all sizes of operation, from native to improved, and representing all types of management practices. The survey collected data from the 2003 and prior pecan growing seasons. The ages reported by Texas pecan producers ranged from 23-90 and averaged 61.7 in 2004. Their proximity to urban communities of 10,000+ inhabitants was >25 miles for 88, 10-25 miles for 68, and <10 miles for 36 producers. Orchard or grove size reported was: <5 acres (n=53), 5-25 acres (n=64), 25-50 acres (n=25), 50-250 acres (n=30), 250-500 acres (n=13), and 500+ acres (n=11). Producers reported the bearing status of their trees as: not yet in production (n=17), in production 1-9 years (n=52), 10-25 years (n=71), 25-49 years (n=48) and 50+ years (n=8). Crop frequency reported was annual for 106 producers, biennial

for 47 producers and triennial or longer for 23 producers. There were 157 producers reporting awareness of the Texas Pecan IPM Program, while 17 were not sure and 22 were unaware of the program. From the 174 producers answering a question relative to their self-designated management programs, 19% did not spray, 24% sprayed less than 3 times/year, 28% used IPM and 29% cited use of a complete program. (Note that TAMUS pecan program characterizes IPM as spraying only when needed using only needed materials; complete programs often contain tank-mixes with one or more unneeded materials and may make more applications).

The producer educational level was reported as: Elementary, 1; High School, 29; Some College, 45; Bachelor's, 61; Graduate Work, 7; and a Graduate Degree, 44. Producer attendance at Annual Meetings of the Texas Pecan Growers Association indicated 50% of producers had attended 4+ meetings, 74% had attended one or more, and 26% had attended none. Virtually all producers relied upon themselves for management decision making (99%), and also sought input from other pecan growers (88%), County Extension Agents (85%), chemical company representatives (50%), the Internet (39%) and public and private pest consultants (35%). Program activities used by producers that provided Pecan IPM information and training included county pecan field days (32%), internet sites (21%), county pecan meetings (20%), Pecan IPM Workshops (19%), and county pecan shows (16%); producers also report using TCE Agents (53%), other growers (45%), Texas Pecan Grower Association meetings (17%), radio (17%), newspaper (15%) and chemical representatives (14%). Printed sources of information used by producers in developing management programs and in making management decisions included Pecan Quarterly (94%), Pecan South (44%), Pecan Culture (Brisson 1974) (38%), Texas Pecan Orchard Management Handbook (22%), Texas Pecan IPM Manual (22%), Texas Pecan IPM Newsletter (20%), Texas Pecan Press (14%), newspaper articles (7%), and the Texas A&M University Pecan Short Course (7%). No direct use by producers of the refereed journal literature was reported. Factors that were always or sometimes considered in making a spray decision included: weather (78%), pest density (77%), plant stage (73%), safety (61%), models (54%), pheromone trap captures (44%), public concerns regarding pesticides (45%) and time needed to apply spray coverage (49%).

Each producer listed losses from his/her top six pests they considered hardest to control and collectively listed more than 20 pests. In 2004, the primary arthropods and diseases noted by producers were pecan nut casebearer (6.1% producer estimated yield loss), pecan scab (5%), hickory shuckworm (2.9%), pecan weevil (2.6%) the stink bug complex (2.1%), blackmargined aphid (1.5%), grasshoppers (1.1%), black aphid (1.1%), fall webworm, phylloxera, walnut caterpillar, downy spot, brown leaf spot, stem end blight, pecan leaf casebearer, mites, scale, spittlebug, cotton root rot, and liver spot, exclusive of rosette (a nutritional zinc deficiency remediated on all pecans by application of zinc amendments to the canopy in the spring when foliage is rapidly growing), squirrels, birds and mammals. In 2004, the top six arthropods and diseases differ from the top six noted in 1997 (Harris et al. 1998), with the stink bug complex displacing the black aphid. During the 1996-2004 period, producer estimated yield losses increased for pecan scab (from 3.8 to 5%) and the stink bug complex (from < 0.5 to 2.1%), while remaining pest losses decreased or stayed about the same resulting in an overall producer estimated yield loss from arthropods and diseases of 23.19% in 2004 compared to 21.91% in 1996 (Harris et al. 1998). In 2004, the top six pests were four arthropod pests of nuts, one of foliage, and a disease that affects nuts and foliage, collectively representing 87% of yield losses attributed directly to arthropods and pathogens. The Texas Pecan IPM Program has prioritized targeting

pests of nuts in decision making involving overt treatments, while urging tolerance of other arthropods and diseases to the greatest extent that monitoring and action thresholds would allow (Harris et al. 1998). This strategy appears warranted in light of the producer experience documented above and was expected to be reflected in their management practices.

Zinc, fungicide and insecticide sprays applied from initiation of foliage at budbreak to completion of kernel development at the dough stage depict the type and timing of treatments made during the season (Fig. 1). The majority of spray applications are made early in the season by complete and IPM program producer, with the remainder made by <3 sprays/year and no-spray producers (the latter do report making zinc sprays). Treatment type and timing correspond with when zinc (early to mid-season), fungicide (varies depending on weather and tree variety), and insecticide (at pollination for pecan nut casebearer and during latter stages of nut development for hickory shuckworm, the stink bug complex and pecan weevil) amendments are most beneficial. The Texas Pecan IPM Program has placed special emphasis on developing decision-making aids for determining if and when to treat for pecan nut casebearer, pecan scab, pecan aphids, pecan weevil and hickory shuckworm (Harris 1983, Harris et al. 1998). The spray phenology indicates these pests are judiciously targeted by producers and that tank mixes target existing problems (Fig. 1).

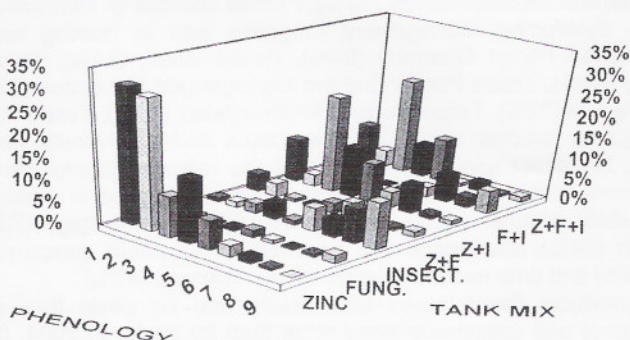


FIG. 1. The percentage of producers treating at each of nine times during the season and the type of application of materials (zinc, fungicide and insecticide) on pecans in Texas. Numerals 1-9 represent nine phenological plant stages corresponding to: Budbreak (1), Prepollination (2), 1st Generation Casebearer I (3), 1st Generation Casebearer II (4), 2nd Generation Casebearer (5), Water Stage (6), Half-Shell Hardening (7), Late-Gel (8), and Dough (9), respectively; Z = zinc, F = fungicide, I = insecticide

The pesticides being used to manage pests (Table 2) show that "at-risk" chemistries represented by organophosphates and carbamates predominate, despite the availability of tebufenozide, spinosad and *Bacillus thuringiensis* based materials and pyrethroids, deemed by some regulators as substitutes. Reliance on "at-risk" insecticides was reduced from 91% in 1996 (Harris et al. 1998) to 71% currently. This is primarily due to adoption of selective insecticides for managing lepidopteran pests. However, they are usually more expensive on a per use basis,

Table 2. Fungicide and insecticide materials applied in Texas based on survey responses of 196 pecan producers for the 2003 growing season. Fungicide "Other" = unspecified combinations.

Fungicide: # Times Sprayed		Insecticide: # Times Sprayed	
Super-Tin	77	Lorsban	148
Other	72	Malathion	118
Enable	55	Sevin	110
Benlate	44	Confirm	99
Topsin-M	29	Dormant oil	22
Orbit	12	Fury	15
Du-Ter	10	Other pyrethroid	14
Cyprex	9	B.t. product	13
Abound	7	Dimethoate	11
Orbit, Enable	6	Lindane	9
Supertin-Orbit	4	Zolone	8
Zyram	2	Thiodan	7
		Spintor	6
		Imidan	6
		Diazinon	3
		Ambush	3
		Guthion	1

although adoption has been aided by research indicating that hickory shuckworm control can be achieved with a single treatment of tebufenozide compared to two treatments generally applied when an organophosphate is used. The organophosphates have experienced judicious, sustained use over several decades in the Texas Pecan IPM Program without the appearance of pest resistance. We attribute this to producers adopting IPM principles and limiting use of broad-spectrum insecticides to situations where a damaging pest is present in sufficient numbers to threaten an otherwise harvestable crop (Harris et al. 1998). Pyrethroids have not been widely adopted because experience elsewhere indicates early season use results in aphid, mite and leafminer outbreaks later in the season, and that repeated use leads to development of resistance in these secondary pests (Harris et al. 1998). Further, carbamate use primarily targets pecan weevil in late-season and no comparable substitute is currently available.

Previous studies show 5.1 insecticide and 4.6 fungicide sprays per season were used in 1980 (Harris et al. 1998) compared to 3.1 insecticide and 1.8 fungicide sprays per season for growers that report spraying these materials (complete and IPM categories). This reduction has occurred despite the temptation to tank-mix insecticide and fungicide treatments with compatible zinc applications, which were applied about equally by producers using complete or IPM programs (Fig. 2). The reduction in fungicide use since 1980 has been adopted by both the Complete and IPM producers (Fig. 2). The reduction in insecticide use since 1980 has been greatest for IPM producers, but both Complete and IPM producers report using less insecticide in successive surveys (Harris et al. 1998, Fig. 2). These results indicate the Texas Pecan IPM Program is reaching and being widely adopted by Complete as well as IPM producers. This view is reinforced by examining the IPM decision aids producers report using in their programs (Figs. 1-3). IPM producers make

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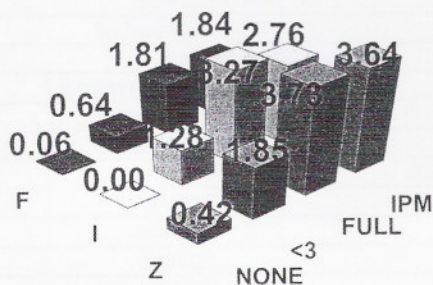


FIG. 2. Average number of spray applications of fungicide (F), insecticide (I), and zinc (Z), by Texas pecan growers categorizing themselves as : None, Less Than Three Per Year, Complete Program, or Integrated Pest Management, producers. Note, materials are often tank-mixed.

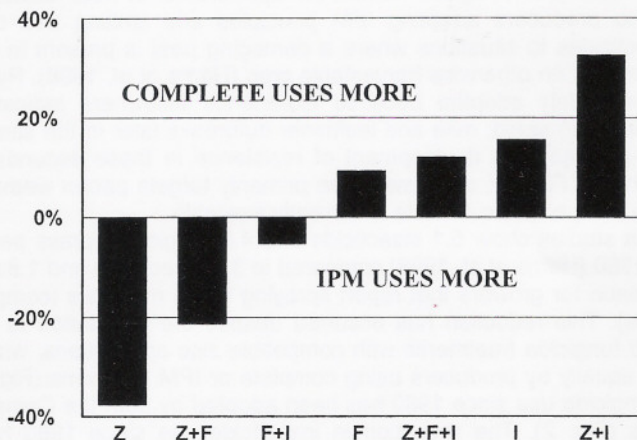


FIG. 3. Comparison of the degree of tank-mixing between Complete Spray Program producers and Integrated Pest Management (IPM) producers in Texas. Z = zinc, F = fungicide, I = insecticide.

greater use of all aid categories followed closely by Complete Program producers, the <3 Spray producers and No Spray producers made less use of decision aids. More than 70% of producers that spray report using at least three IPM decision aids in making management decisions.

Pesticide application, as reported by 177 producers, was made by a power take-off airblast sprayer (42%), hand gun (40%), engine-driven airblast sprayer (13%), electrostatic sprayer (2%) or airplane (2%). These included 563 zinc applications, 555 insecticide applications and 327 fungicide applications made between budbreak and leaf drop. The degree of tank mixing by Complete Program producers using a complete (full) program, particularly with insecticides added to zinc treatments, was greater than that practiced by producers following IPM programs, who appear to be targeting treatments better and spraying zinc by itself if damaging insect densities are absent (Fig. 3). We note that fungicide and zinc use among these producer groups is virtually equal (Fig. 2) so that the 0.68 difference in insecticide sprays accounts for the major difference in programs and provides insight into how to target educational topics better to encourage producer adoption. This was also recognized earlier and IPM program delivery emphasis has stressed limiting tank mixing to occasions where all materials are needed; the previous difference among programs in 1996 was 0.9 insecticide sprays and the incremental reduction of 0.22 during the interim has been primarily achieved by Complete Program producers reducing their total number of insecticide sprays (Harris et al. 1998). Producer application of fungicides averaged 1.84 sprays per season in 2003 (Fig. 2) compared to 2.9 in 1996 (Harris et al. 1998). Fungicide use primarily targets pecan scab and research shows that risk is greatest from budbreak through mid-season when ascospores and later, conidia, germinate on rapidly growing foliage or nuts of susceptible varieties following rains. Educational programs have emphasized growing "resistant" varieties that are easier to protect with fungicide, and to only treat when weather conditions are suitable for disease development (a "wetting period" model concept). The most effective fungicide deemed to protect foliage, propiconazole, and the most effective deemed to protect nutlets, triphenyltin hydroxide, were co-packaged for sale and tank-mix use in 1996 and have been widely adopted and judiciously used by Texas producers based upon the current survey results. The reduction of one fungicide spray by both producer groups represents, in our judgment, the success of education programs resulting in producer confidence in decision making processes and in the materials being effective when they are needed. Zinc sprays increasingly represent the principal spray material applied to pecans as the sole active ingredient (42% of the time for IPM producers and 35% for Complete Program producers); this compares with IPM producers spraying only with zinc 18% of the time and Complete Program producers 21% of the time in 1994 (MKH, unpublished). The number of zinc applications per grower has remained steady between 4 and 4.5 treatments per year for the past 25 years (Harris et al. 1998, and the present study). This shift in producer behavior clearly reflects how reduction in insecticide and fungicide use in the Texas Pecan IPM Program is being achieved. Producers have been educated to target pest problems and only use those materials that are needed to protect their crop, despite the temptation to tank-mix other compatible materials during the conduct of necessary spray operations (Harris 1992).

The Pecan IPM Program has been remunerative to the producers of Texas with overall economic benefits calculated to be in excess of \$6 million annually (Harris et al. 1998). Compared to 1996, the current survey shows additional reductions in fungicide (1.1) and insecticide (0.3) applications/season for all producers that treat. Extrapolation of the resulting cost savings to Texas producers

as a whole using methodology detailed in Harris et al. (1998) and using 1996 dollar values for direct comparison, results in calculations of \$29.10/ha in fungicide and \$8.60/ha in insecticide costs, totaling \$37.70/ha reduction in costs of materials compared to the previous survey (\$832,000 in 1995 and adjusting for an increase of 24% in the Consumer Price Index [CPI] results in \$1.03 million in 2004). We are confident that the reduction in fungicide use is directly related to the Pecan IPM education effort and the adoption of IPM principles by producers, but we are not confident that the reduction in fungicide use can be sustained because adherence to the same principles will result in increased use in wetter years as observed (but not as yet documented) in the 2004 growing season. Conversely, the persistent incremental progress in reducing insecticide use since the inception of the program some 25 yrs ago (Harris et al. 1998) does appear to be sustainable. Thus, the current program impact of \$1 million (over an estimated 22,100 ha of managed improved pecans in Texas) in material cost savings above that calculated in Harris et al. (1998) is probably not sustainable given the inconsistencies of Texas weather. These challenges may require producers to increase fungicide use in wetter years to protect vulnerable varieties. The evidence shows, however, that pesticide use is being minimized consistent with producing a harvestable crop. This contributes to keeping pecan producers economically viable and able to market high quality pecans at a lower but profitable price, thereby benefiting consumers as well.

The major benefits to society from producer adoption of IPM certainly include the availability of abundant, wholesome food at affordable prices. Other major benefits include the reduction in environmental stresses that affect everyone when less pesticide is used. The Texas Pecan IPM Program has documented a reduction in insecticide application from 5.1 treatments in 1980 to 3.1 in 2003. The principal insecticide used on pecan has been an organophosphate (initially phosalone and now chlorpyrifos (\$23.30/kg of ai) applied at a labeled rate of 1.12 kg ai/ha, constituting about 67% of all insecticide applications through 1996 and 52% in the current study. The current 15% reduction reflects a substitution of tebufenozide (\$220/kg of ai), as noted above, at a labeled rate of 0.56 kg ai/ha having occurred since 1996. These data show the reduction in insecticide use from 5.1 to 3.1 applications since the inception of the program in 1980 is due to the reduced use of organophosphate insecticide. This currently results in 162,809 kg ai of organophosphate not being applied, with a material cost savings to Texas producers of \$3.8 million annually. We note that a small (<10%) substitution of pyrethroids for organophosphates has occurred since the inception of the program and that the former are sprayed at rates about 0.1 that of the latter. We have not attempted to capture this above because in our view, it is the reduction in sprays (and period of prophylactic coverage) rather than the substitution of one poison for another that constitutes real progress in IPM.

Similar calculations over the same time period for fungicide use are confounded by numerous factors: 1) weather; 2) the complexity of fungicide use reflected in the 5+ comparable surveys conducted at various intervals from 1980-2004; 3) variabilities in rates among materials (where a reduction in ai may be achieved by substitution, but no reduction is achieved in number of sprays applied); 4) the trend observed in the present study to combine fungicides in the same spray (23% currently as compared to <10% previously); and 5) reconciling material cost savings through time. The record shows that 4.6 fungicide applications were made in 1980, followed by 3.2 in 1990, 3.4 in 1993, 3.0 in 1996 and 1.8 in 2003. This reflects a consistent reduction since 1980 of 1.4 to 2.8 fungicide applications per year and we conservatively estimate a sustainable average reduction of 1.6 fungicide treatments per year has occurred due to the IPM program effort. Based on

1996 costs and usage adjusted to the CPI, the average fungicide material cost is estimated to be \$32.81/ha/application. Since fungicide is typically applied in early season when zinc is also needed, no application costs are calculated; material costs for fungicides are further corrected for the current increased use of combinations by an estimated 15%, resulting in a current fungicide material cost of \$37.74/ha. This results in a current fungicide material cost savings of 1.6 applications (= \$60.34/ha) based on current practices. Realistically, however, the material cost savings for applications not made due to improvements brought about by IPM program inputs have been estimated based upon past program practices (= \$32.81/ ha/ treatment) minus 15% because of current use of combinations of fungicides, resulting in cost savings of \$27.91/ha/application. The principal fungicide applied in 1980 was benomyl at a rate of 0.8kg/ha. This reduction of 1.6 fungicide applications currently reduces the fungicide load on the environment by an estimated 1.3 kg ai/ha annually, resulting in 29,000 kg ai of benomyl (or any other fungicide because this is a spray reduction) not being applied, with a material cost savings to Texas producers of \$604,000 annually.

Summary and Conclusions

The Texas Pecan IPM Program has developed strategies and tactics through research that have been effectively communicated to producers resulting in significant behavioral changes in management practices. The primary sources of information producers use to develop and implement their management programs are personal contacts and grower oriented media. There is an increasing adoption of resources from the world-wide web and electronic communications. Refereed journal literature is not directly used by producers. During the past 25 years, both Complete program and IPM producers have been reducing insecticide and fungicide applications and timing them better. Producers continue to improve the judicious use of pesticides. This reduces risk of loss due to pest resistance, conserves natural enemies, and minimizes adverse impacts on the applicator, the consumer and the environment. The overall reduction in pesticide is currently estimated to be 192,000 kg/yr, less than the amount used in 1980 with a material cost savings to producers of \$4.4 million/yr in Texas.

Reduction of "at risk" insecticide applications from 91% (1996) to 71% (2003) is due to both the substitution of tebufenozide and fewer applications overall. Alternative insecticides do exist for pecan nut casebearer, but may be considered more expensive (tebufenozide has become more cost-competitive) and/or less effective or less compatible with IPM (i.e., pyrethroids); and, alternatives to carbaryl for pecan weevil (pyrethroids) are less effective, less compatible with IPM, and require more applications.

Texas pecan producers are responsible stewards of the land, have overwhelmingly adopted IPM and increasingly use alternative chemistry. Further incremental improvements are expected in overt producer adoption of the IPM program in Texas. Current use of insecticides and fungicides consists of about three sprays per season and reflects about 21 days of prophylactic coverage, assuming a seven day residual, in a crop with a 240 day growing season. Continued research and education programs are needed to maintain progress and to develop and integrate new technologies through education of current and new stakeholders that become involved with the industry. The continued need to routinely apply foliar zinc amendments to remediate rosette will provide a temptation to tank-mix other pesticides with these needed zinc treatments.

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