Peanut Production In Systems Restricting Use of Pesticides Based on Carcinogenicity or Leachability[1]

C. K. Kvien*, A. K. Culbreath, J. W. Wilcut, S. L. Brown and D. K. Bell[2]

ABSTRACT

This research was conducted to determine the short-term impact of potential broad sweeping changes in pesticide registrations on peanut production and to compare and improve pest management systems for peanuts. In this research, detailed records on production inputs and returns were kept to access the short-term economic impact of each of six production systems differing in pesticide use. The preventative management strategy required additional pesticide inputs and averaged $180 per hectare less return when compared to the non-restrictive IPM program. When non-restrictive IPM programs were compared to IPM systems that eliminated carcinogens, return to management per hectare declined $1010 and $516 for the cultivars Florunner and Southern Runner respectively. The exclusion of the fungicide chlorothalonil was the primary reason for this loss in revenue. Elimination of compounds most likely to leach, based on their relative leaching potential, had minimal impact on peanut production. All test locations had low nematode pressures. The organic production strategy had the highest pre-harvest variable costs, due to the high input of hand labor required for weeding. To produce returns similar to an unrestricted IPM system, a raw agricultural commodity price 1.95 times that of the IPM system would have to be offered to organic growers.

Key Words: Groundwater, Delany, 409 tolerance, IPM, organic production

The 1992 ninth circuit court ruling on the Delany issue (*Les v. EPA*, CA 91-70234), which overturned EPA's *de minimis* policy on carcinogenic pesticide residues in processed food, and studies such as the 1987 National Academy of Science (NAS) "Regulating Pesticides in Food: The Delany Paradox" and the 1993 NAS "Pesticides in the Diets of Infants and Children" increase pressure on U.S. agriculture to speed development of production practices that do not rely heavily on pesticide use. The above mentioned studies suggest that risks from pesticides should be calculated as cumulative risks from pesticide groups rather than from single pesticides. The incidence of pests, including weeds, insects, pathogens, and nematodes, is high in the Southeastern U.S. Therefore, pesticide use on peanut is extensive; herbicides alone amount to an annual total of over 2.3 million kilograms of active ingredient used in U.S. peanut production (Gianessi and Puffer, 1990).

The southeastern region's peanut growing soils are sandy, with low cation exchange capacities, which is conducive for pesticide leaching through the profile. The peanut crop also relies on several pesticides classified by EPA as carcinogens, and these compounds will be under additional scrutiny as a result of the ninth circuit court ruling on Delany. These facts, together with the peanut's importance as a children's food, emphasize the need for information on the impact of potential pesticide registration changes on production, and the need for alternative production systems that do not rely as extensively on pesticide inputs as the ones currently in use. Therefore, during production years 1990, 1991 and 1992 we conducted comparative pest management programs with varying levels of pesticide input restrictions to determine the short-term impact on peanut production of potential changes in pesticide regulation.

Methods

Six (1991 and 1992) systems of peanut production differing in chemical inputs (based on EPA carcinogenicity class and relative leaching potential) were compared on 0.1 hectare replicated (split plot design with three replicates, system being the main plot, cultivar the sub-plot) plots at two University of Georgia research farm locations (near Tifton and near Plains) during two years (1991-92). Additionally, four of the six systems of production were tested at both locations in 1990. The Tifton site was a non-irrigated Tifton loamy sand (fine-loamy, siliceous, thermic Plinthic Kandiudults) with a pH of 6.2. The Plains site was an irrigated Greenville sandy clay loam, (clayey, kaolinitic, thermic Rhodic Kandiudults) with a pH of 6.2. In 1990 both sites were formerly in bermuda grass pasture for 10 years prior to this experiment. In 1991 and 1992, both sites had been in corn the year before the experiment, in cotton two years before the experiment and in peanut three years before the experiment. Representative to the area, moderate levels of pest pressures (diseases, insects and weeds) existed at both locations. Nematodes were not a major pest at either location.

[1]Contribution from the Georgia Agricultural Experiment Station, University of Georgia. Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product and does not imply its approval to the exclusion of other products that may be suitable.

Along with State and Federal Experiment Station funds, this study was aided financially by the National Pesticide Impact Assessment Program, the National Peanut Council and the Georgia Peanut Commission.

[2]Crop Physiologist, Dept. of Crop and Soil Sciences, Coastal Plain Station, University of Georgia, P. O. Box 748, Tifton, GA 31793; Pathologist, Plant Pathology, Coastal Plain Station; Weed Scientist, Crop and Soil Sciences, Coastal Plain Station; Extension Entomologist, Rural Development Center, Tifton, GA, and Pathologist, Plant Pathology, Coastal Plain Station.

*Corresponding author.

Table 1. Carcinogenicity and Relative Leaching Potential Classifications of Pesticides Available For Use on Peanuts[1].

FUNGICIDES

Common Name	Example of Trade Name	Carcinogenicity Classification	Relative Leaching Potential
Benomyl	Benlate	C	79
Captan	Captan	B_2	800
Carboxin	Vitavax	Neg 2 sp	867
Chlorothalonil	Bravo	B_2	460
Copper Am Carbonate	Copper-Count-N	NC	NC
Copper Hydroxide	Kocide	NC	NC
Basic Copper Sulfate	Basicop	NC	NC
Etridiazole	Terrazole	B_2	>2000
Iprodine	Rovral	Neg 2 sp	500
Mancozeb	Dithane M-45	NC	286
Metalaxyl	Ridomil	E	7
Metiram	Polyram	Neg 1 sp	NC
PCNB	Terraclor	C	>2000
Sulfur	Uniflow	NC	NC
Thiophanate-methyl	Topsin	Neg 2 sp	1830
Thiram	Thiram	NC	447
Triphenyltin Hydroxide	Du-ter	NC	NC

HERBICIDES

Common Name	Trade Name	Carcinogenicity Classification	Relative Leaching Potential
2,4 DB	Butyrac	NC	20
Acifluorfen	Blazer	B_2	81
Alachlor	Lasso	B_2	3
Benefin	Balan	E	>2000
Bentazon	Basagran	NC	17
Clorimuron	Classic	Neg 1 sp	28
Ethalfluralin	Sonalin	Pending- Evidence in rats	667
Fenoxyaprop	Whip	NC-Neg 2 sp	>2000
Imazethapyr	Pursuit	NC-Neg 1 sp	NC
Metolachlor	Dual	C	22
Paraquat	Starfire	E	>2000
Pendimethalin	Prowl	NC	556
Sethoxydim	Poast	NC-Neg 2 sp	200
Trifluralin	Treflan	C	1330
Vernolate	Vernam	NC Neg 1 sp	217

INSECTICIDES

Common Name	Trade Name	Carcinogenicity Classification	Relative Leaching Potential
Acephate	Orthene	C	7
Aldicarb	Temik	NC	10
Bacillus thuringiensis	Dipel	NC	NC
Carbaryl	Sevin	NC	300
Chlorpyriphos[2]	Lorsban	Neg 1 sp	>2000
Disulfoton	Di-Syston	Neg 2 sp	200
Esfenvalerate	Asana	NC	1510
Fonofos[2]	Dyfonate	NC	NC
Malathion	Malathion	D	>2000
Methomyl	Lannate	Neg 2 sp	24
Phorate	Thimet	Neg 2 sp	167
Propargite	Comite	Neg 1 sp	714

NEMATOCIDES/FUMIGANTS

Common Name	Trade Name	Carcinogenicity Classification	Relative Leaching Potential
Aldicarb	Temik	NC	10
1,3-Dichloropropene	Telone II	B_2	32
Ethoprop[2]	Mocap	NC	28
Fenamiphos	Nemacur	Neg 1 sp	20
Metam-sodium	Vapam	NC	14
Oxamyl	Vydate	Neg 2 sp	63

[1]**Carcinogenicity Classifications:** B_2 = probably human carcinogen; C = possible human carcinogen; NC = not classified or not classified as a carcinogen. Neg 1 (or2) sp = Negative on one (or two) species of test animal(s) but not yet classified. Source: USEPA/OPP RFD Tracking Report, January 6, 1993. **Relative Leaching Potential:** The smaller the RLPI value of a pesticide the greater is its potential to leach. Source: Hornsby, et al., 1991.

[2]Also documented to have some fungicidal activity against Sclerotium rolfsii.

Although over two-hundred pesticides are registered by EPA for use on peanuts, only 19 fungicides, 15 herbicides, 13 insecticides and 7 nematicides are in use on more than 1% of the peanut hectarage (National Peanut Council, 1991). Of these, over half have no carcinogenicity classification and, in general, the relative leaching potential of most of the compounds is calculated only for the parent compounds, and not their metabolites (Table 1). Therefore, when choosing pesticides to avoid because of carcinogenicity we chose to avoid only those currently classified by EPA as B or C carcinogens (USEPA/OPP, 1993). To minimize the use of pesticides which may have the greatest likelihood of entering groundwater, we used Hornsby et al's. (1991) relative leaching potentials (RLP), choosing only pesticides having an RLP of greater than 35. The six comparison production systems (1991 & 1992) and the pesticides used to control pests in each system are listed below. In 1990 only production systems 1, 2, 3 and 6 were studied.

(1) Preventative management.

Since many growers have large hectarage to manage, some choose to apply pesticides based on an anticipated need rather than on a scouting report. This strategy may result in higher pesticide inputs.

Herbicides used in this system included pendimethalin (Prowl, 1.1 kg ai ha^{-1}, American Cyanamid, Wayne, NJ) and imazathapyr (Pursuit, .071 kg ai ha^{-1}, American Cyanamid) applied preplant incorporated (PPI), followed by postemergence (POST) treatments of bentazon (Basagran, 0.56 kg ai ha^{-1}, BASF, Research Triangle, NC), paraquat (Starfire, 0.137 kg ai ha^{-1}, Zeneka Ag Products, Wilmington, DE), chlorimuron (Classic, 0.009 kg ai ha^{-1}, DuPont, Wilmington, DE), and 2,4-DB (Butoxone 175, 0.24 kg ai ha^{-1}) as needed.

Insecticides included aldicarb (Temik 15 G, 1.16 kg ai ha^{-1}, Rhone-Poulenc, Raleigh, NC) for thrips (*Frankliniella sp.*) and chlorpyrifos (Lorsban 15 G, 1.1 kg ai ha^{-1}, DowElanco, Indianapolis, IN) at flowering for control of the lesser cornstalk borer (*Elasmopalpus lignosellus*). Chlorpyrifos was used only at our non-irrigated Tifton location since this pest is mostly associated with drought. Methomyl (Lannate, 0.38 kg ai ha^{-1}, E.I. Du Pont de Nemours & Co., Wilmington, DE) was used to control foliage feeding larvae when present. Propargite (Comite, 1.83 kg ai ha^{-1}, Uniroyal Chemical Co., Inc. Middlebury, CT) was used to control the two-spotted spider mite when present.

Fungicides included a seed treatment of Captan + DCNA (Bo-Tec, 93.6 g ai + 93.6 g ai 100 kg^{-1} seed, Nor-Am Co., Naperville, IL), chlorothalonil (Bravo 720, 1.26 kg ai ha^{-1}, ISK Biotech, Mentor, OH) and sulfur (Uniflow, 3.3 kg ai ha^{-1}, Uniroyal Chemical Co., Middlebury, CT) on a 14 day schedule starting 30 days after planting for control of leafspots caused by *Cercosporidium personatum* (Berk. & Curt.) Deighton and *Cercospora arachidicola* S. Hori, and PCNB (Terraclor 10 G, 56 kg ai ha^{-1}, Uniroyal, Middlebury, CT) 45 days after planting for control of southern stem rot (*Sclerotium rolfsii* Sacc.). *Rhizobium* (LiphaTech, 411 g material 100 kg^{-1} seed, Milwaukee, WI) seed inoculants were used in all three test years at all locations in this production system.

(2) Intensely monitored pest control approach using integrated pest management (IPM) practices to control pests and determine benefits of all pesticides applied.

Herbicides used in this system included pendimethalin applied PPI (as in system 1), followed by POST treatments of paraquat, bentazon and 2,4-DB (rates as in system 1) as needed according to scouting reports (scouting costs for systems 2-6 were included as part of labor costs). Insecticides were also applied according to field history and scouting reports and sometimes included aldicarb (based on field history, rate as in system 1) at planting for thrips, chlorpyrifos (based on scouting reports, rate as in system 1) for lesser cornstalk borer, methomyl (based on scouting reports, rate as in system 1) and propargite (based on scouting reports, rate as in system 1) to control the spider mite. Fungicides included the seed treatment of Captan + DCNA (as before) and chlorothalonil + sulfur (rates as before) applications according to the Auburn University weather-based leaf spot advisory model (AUPNUTS) (Brannen and Backman, 1992). Initial chlorothalonil applications were made after a cumulative total of seven rain events (>0.24 cm/event) had occurred after seedling emergence. After the first chlorothalonil application, determination of subsequent spray timing was made from a combination of weather forecasts and rain events that occurred after a 10 day protection period. For example, fungicide application was made if two rain events had occurred and the average 5 day probability of rain was greater than 20%. Scouting reports were used to determine if treatment for southern stem rot was needed. No applications were deemed necessary for this disease at any test site. *Rhizobium* seed inoculants (as in system 1) were used only in 1990 (the land had not been in peanuts for at least 5 years). In 1991 and 1992 rotations were short enough to provide adequate *Rhizobium* without inoculant use.

(3) IPM practices as above except using no pesticides classified by EPA as possible or probable human carcinogens (such as acephate, acifluorifen, alachlor, benomyl, captan, chlorothalonil, 1,3-dichloropropene, metolachlor, and trifluralin).

Herbicides used in this system included benefin (Balan, 1.65 kg ai ha^{-1}, (DowElanco, Indianapolis, IN) and imazethapyr (as before) applied PPI followed by POST treatments of paraquat (as before), bentazon (as before) and 2,4-DB (as before) when needed according to scouting reports. Insecticides were also applied according to field history and scouting reports and sometimes included aldicarb at planting for thrips, chlorpyrifos for lesser cornstalk borer and DiPel (1.1 kg ai ha^{-1}, Abbott Laboratories, Chicago, IL) for foliage feeding insects. Because Captan is a B_2 carcinogen, only biological seed treatments were used. In all test plots of this system, seed were protected using a combination of a powder peat based *Rhizobium* seed inoculant (LiphaTech, 411 g material 100 kg^{-1} seed, Milwaukee, WI) and a *Bacillus subtilis* (Quantum 4000, 500 g material 100 kg^{-1} seed, Gustafson, Inc., Plano, TX) inoculant. Prior to planting, seed that were protected by the biologicals exclusively (systems 3, 5 and 6) were tested and some seed sources were rejected when seedling emergence was unsatisfactory (less than 70%). Foliar applications of basic copper sulfate (Basicop, 3.3 kg material ha^{-1}, Griffin Corp., Valdosta, GA) and sulfur (as in system 1) were applied according to AUPNUTS in 1990 and 1991; in 1992 only sulfur was applied.

(4) IPM practices as above except using no pesticides classified as having relative leaching potentials less than 35. Therefore compounds such as 1,3-dichloropropene, 2,4-DB, acephate, alachlor, aldicarb, bentazon, chlorimuron, DCP + MITC, di-chloropropene, ethoprop, fenamiphos, metalaxyl, metam-sodium, methomyl, metolachlor, MIT, and trifluralin were disallowed.

Herbicides used in this system included pendimethalin (as before) and imazethapyr applied PPI, followed by POST treatments of paraquat as needed according to scouting reports. No insecticides were applied (1990 was the only year foliage feeders and lesser cornstalk borers required treatment, and systems 4 & 5 were not studied this year). Fungicides included Captan + DCNA (seed) and chlorothalonil + sulfur (for leafspot) according to AUPNUTS. *Rhizobium* seed inoculants were used only in 1990.

(5) IPM practices as above except using no pesticides classified as either possible or probable human carcinogens or as having a high potential for leaching to groundwater. In this system, both of those compounds restricted in system 3 and in system 4 were disallowed.

Herbicides used in this system included benefin and imazethapyr applied PPI followed by POST treatments of paraquat as needed according to scouting reports. No insecticides were applied. Seed were treated with a combination of *Rhizobium* and *Bacillus subtilis*. Foliar applications of basic copper sulfate + sulfur (in 1990 and 1991, rates as before) or sulfur alone (1992) were made according to AUPNUTS.

(6) Biologically intensive using good management practices and only pesticides allowed under the rules of the California Certified Organic Farmers organization (1991 Certification Handbook).

In 1990 a fatty acid containing herbicide (Sharpshooter, 6 L ha^{-1}, Mycogen, San Diego, CA) was tried as a pre-cracking treatment. In 1991 and 1992 weed control was entirely accomplished by tillage, cultivation and hand weeding. Basic copper sulfate and sulfur (rate as before) were used to control leafspots in 1990 and 1991. In 1992 only sulfur was used. DiPel was used (rate as before) for foliage feeding insect control in 1990. *Rhizobium* and *Bacillus subtilis* were used as seed protectants.

Both the standard highly productive cultivar Florunner and the more disease resistant cultivar Southern Runner were used in all 1991 and 1992 production systems. Only Southern Runner was used in the 1990 study. Pesticide applications within a management system did not differ due to cultivar. The hull-scrape procedure (Williams and Drexler, 1981), pod stem strength and canopy health were used in combination to help determine the best harvest date for each of the six systems. Yield and grade were collected for all plots.

Plots were arranged in a split plot design with system being the main plot and cultivars the sub-plot. Statistical analysis was accomplished using the General Linear Model of SAS (SAS, 1989) and analyzed as a split plot design with system as the main plot and cultivar as the sub-plot. Enterprise budgets for each production system were developed. Observations of prices for alternative inputs indicated that the relative costs were essentially unchanged. Therefore, to standardize comparisons between years, input prices and output market prices were fixed at 1992 levels. Domestic quota prices, factoring in changes due to grade, were used to calculate market prices for all production systems. Annual differences in total pre-harvest variable costs primarily came from seasonal variations due to rotations, field variability, fertilization, pesticide inputs, labor and irrigation expenses.

The calculated enterprise budgets contain only those costs which may be directly assigned to peanut production. Additional costs, sometimes substantial, are related to the whole farm operation. For example, cost of land was based on local rent values, not fair market value. Producers' financial structuring can create considerable differences in the charges attributed to land cost. These additional whole farm costs should be included when making estimates of whole farm profitability.

Results and Discussion

Large farms often resort to prophylactic treatment of pests based on field history. Additional pesticides are used as a type of insurance. In our studies, the preventative pest management strategy resulted in a combined 1991 and 1992 average over all locations of $437 per hectare in pesticide costs compared to $276 per hectare in the IPM system (Table 2). Since yield and grade remained approximately the same in both systems (Table 3), the average (over both years and locations) $183 reduction in total return per hectare from this system when compared to the IPM system (Table 4) was largely ($161) due to increased pesticide input (Table 2).

The more disease resistant Southern Runner cultivar produced less return per hectare than Florunner at the irrigated Plains location under the preventative and non-restrictive IPM management system (Table 4). However, at the non-irrigated Tifton location Southern Runner return equaled that of Florunner. In general, the non-irrigated

Table 2. The Effect of Pest Management Strategy on Selected Pre-Harvest Management Costs For Peanuts.

PEST MANAGEMENT STRATEGY	PESTICIDE INPUT $/ha							
	PLAINS				TIFTON			
	90	91	92	91-92 AVG	90	91	92	91-92 AVG
PREVENTIVE	368	363	435	400	282	484	462	474
IPM	294	277	267	272	225	418	294	279
IPM w/o CARCINOGEN	170	190	96	143	106	175	124	148
IPM w/o GROUNDWATER HAZ		213	220	217		213	220	217
IPM w/o CARCINOGEN or GROUNDWATER HAZ		126	74	99		119	74	96
ORGANIC (COGA)	170	54	15	35	195	124	15	69

PEST MANAGEMENT STRATEGY	HAND WEEDING LABOR $/ha							
	PLAINS				TIFTON			
	90	91	92	91-92 AVG	90	91	92	91-92 AVG
PREVENTIVE	161	86	114	99	17	30	86	59
IPM	128	82	138	109	20	27	91	59
IPM w/o CARCINOGEN	203	72	128	99	30	47	111	79
IPM w/o GROUNDWATER HAZ		94	104	99		30	69	49
IPM w/o CARCINOGEN or GROUNDWATER HAZ		72	128	99		35	69	52
ORGANIC (COGA)	766	1008	754	880	833	759	2461	1611

PEST MANAGEMENT STRATEGY	TOTAL PRE-HARVEST VARIABLE COSTS $/ha							
	PLAINS - PHV				TIFTON - PHV			
	90	91	92	91-92 AVG	90	91	92	91-92 AVG
PREVENTIVE	1102	1124	1238	1142	709	1151	1142	1102
IPM	988	1028	1087	1018	652	922	969	899
IPM w/o CARCINOGEN	998	927	897	872	603	843	813	731
IPM w/o GROUNDWATER HAZ		974	998	946		865	870	823
IPM w/o CARCINOGEN or GROUNDWATER HAZ		860	870	825		768	714	697
ORGANIC (COGA)	1619	1772	1468	1581	1542	1537	3175	2313

Table 3. The Effect of Production Management Systems on Peanut Yield Per Hectare.

PEST MANAGEMENT STRATEGY	FLORUNNER						SOUTHERN RUNNER							
	PLAINS - Mg/ha^{-1}			TIFTON - Mg/ha^{-1}			PLAINS - Mg/ha^{-1}				TIFTON - Mg/ha^{-1}			
	91	92	AVG	91	92	AVG	90	91	92	AVG	90	91	92	AVG
1.PREVENTIVE	3.58	4.68	4.12a	3.43	3.54	3.49a	4.23	3.23	3.67	3.45a	2.42	3.27	4.41	3.85a
2.IPM	3.54	4.75	4.14a	3.40	3.74	3.58a	4.46	3.56	3.49	3.54a	2.28	3.23	4.05	3.63a
3.IPM w/o CARCINOGEN	1.61	2.28	1.95c	2.96	2.60	2.78b	3.88	2.35	2.84	2.60b	1.72	2.96	2.55	2.76b
4.IPM w/o GROUNDWATER HAZ	3.02	4.68	3.85a	3.61	3.63	3.63a		3.09	3.23	3.16a		3.00	4.08	3.54a
5.IPM w/o CARCINOGEN or GROUNDWATER HAZ	1.72	2.80	2.26b	2.96	2.69	2.82b		2.42	2.78	2.60b		2.76	2.44	2.60b
6.ORGANIC (COGA)	1.79	1.90	1.84c	2.35	2.46	2.42c	3.90	2.15	3.34	2.73b	1.75	2.73	2.64	2.69b

Table 4. The Effect of Production Management Systems on Financial Return Per Hectare For Peanuts

PEST MANAGEMENT STRATEGY	FLORUNNER						SOUTHERN RUNNER							
	PLAINS - $/ha			TIFTON - $/ha			PLAINS - $/ha				TIFTON - $/ha			
	91	92	AVG	91	92	AVG	90	91	92	91-92 AVG	90	91	92	91-92 AVG
1.PREVENTIVE	524	1473	998b	786	1169	976a	1035	237	403	321b	472	554	1485	1018a
2.IPM	796	1680	1238a	986	1211	1100a	1268	667	437	554a	385	820	1470	1147a
3.IPM w/o CARCINOGEN	40	30	35d	726	-168	279b	961	-52	227	89c	32	672	492	578b
4.IPM w/o GROUNDWATER HAZ	776	1712	1245a	1193	904	1050a		324	294	309b		682	1510	1095a
5.IPM w/o CARCINOGEN or GROUNDWATER HAZ	247	442	343c	751	37	395b		64	178	121c		615	440	539b
6.ORGANIC (COGA)	-833	-865	-848e	-479	-2372	-1426c	363	-1023	96	-465d	-924	-153	-1841	-998c
ORGANIC w/PREMIUM ($1.65/kg)	1322	803	1063	1557	-867	346	3768	818	3010	1913	588	2152	398	1275

Tifton loamy sand was drier and one degree C warmer than the irrigated Greenville sandy clay loam, of the Plains site. The harvest date for Southern Runner also averaged 10 days later than Florunner. Since we could not have irrigated and non-irrigated plots at each location, we cannot determine specific reasons for this location-cultivar interaction.

Strong pest pressures and the lack of effective alternatives, including resistant cultivars, has resulted in the development of peanut production strategies that are dependent on several pesticides. Early and late leafspots (caused by *C. arachidicola* and *C. personatum*) are two of the most serious diseases of peanut (Gibbons, 1979; Jackson and Bell, 1969). Even with fungicide control programs, losses to these diseases are estimated at between 5% and 10% of the U.S. crop (Garren and Jackson, 1973). In areas where fungicide use is rare, losses to these diseases are commonly 50% or more (Smith and Littrell, 1980). Recommended management practices to help control these diseases include crop rotation (Kucharek, 1975), the destruction or deep turnings of peanut vine residues (Garren and Jackson, 1973), the use of environmentally-based leafspot control advisory models (Bailey and Spencer, 1982; Phipps, 1982; Phipps and Powell, 1984; Brannen and Backman, 1992), the application of fungicides (Smith and Littrell, 1980), and the use of resistant cultivars (Chiteka *et al.*, 1987).

In our studies, the IPM system eliminating class B & C carcinogens resulted in a significant dollar loss returned to management when compared to a standard IPM program (Table 4). The primary reason for this loss was due to the elimination of chlorothalonil, which normally provides leafspot control, from the system. Basic copper sulfate was only minimally effective at controlling the leafspot diseases. We believe the expense of basic copper sulfate, together with the potential long-term problem of copper build-up in the soil, outweighed any benefits in leafspot control and therefore used only sulfur as a substitute for chlorothalonil in 1992.

Eliminating the seed treatment fungicides, because of their carcinogenicity classification, captan, PCNB and etridiazole could result in poor stands, further reducing yields. In our studies we carefully tested seed for quality (conducting emergence tests without fungicides) and used very high quality seed. We combined seed testing with biological seed treatments and planted in warm, moist soil to minimize the potential for poor stands.

When compared over years and locations, the IPM system restricting carcinogens (system 3) resulted in yields 38% and 26% less than the unrestricted IPM system (system 2) for Florunner and Southern Runner, respectively. The return per unit of land was also slightly greater for the disease resistant Southern Runner cultivar than the Florunner cultivar when pesticides classified as carcinogens were restricted from use. When the carcinogen restricted system was compared over all locations and years to the unrestricted IPM system, the difference in return per hectare was $1010 ($158 versus $1168) and $516 ($334 versus $850) for Florunner and Southern Runner respectively (Table 4). Part of the smaller percentage reduction associated with Southern Runner is likely due to the partial resistance and tolerance to late leafspot (Gorbet *et al.*, 1986). Although pesticide inputs in the carcinogen restricted system were 52% of the standard IPM system (Table 2), both yield and return per hectare were significantly reduced when carcinogens were restricted, particularly at the irrigated Plains site (Tables 3 and 4). System 4 restricted use of pesticides classified as having a high potential for leaching to groundwater. We found these class compounds to have a much smaller impact on yield than those classified as carcinogens, primarily because effective alternatives were available. However, our studies were not conducted on soils with high populations of plant parasitic nematodes.

Since EPA uses toxicity as a primary criterion for restricting the application of chemicals, Phipps et al. (1990) conducted a study to determine the effect of blanket elimination of pesticides according to LD_{50} values. The researchers sorted all pesticide treatments according to acute oral LD_{50} values. When treatments were restricted to pesticides with an LD_{50}>5000 crop value declined from $2465/ha in the unrestricted treatments to $1889/ha. This $576/ha decline was only partially offset by a $332 reduction in pesticide costs (from $525/ha with no pesticide-use restrictions to $193 for the LD_{50}>5000 restricted treatment). Phipps, et al. (1990) attributed this decline in return to a significant increase in *Meloidogyne hapla* root galling and thrips injury resulting from the elimination of aldicarb from the system.

In our studies, only Southern Runner at the Plains location showed any reduction in return per hectare as a result of pesticide restrictions based on groundwater concerns. This response may have been due to heavy thrips damage at Plains that resulted in further delaying the development of Southern Runner. This cultivar typically is slower in its canopy development than Florunner, (Gorbet et al., 1986) and we speculate that the thrips pressure, which could have been controlled in a system allowing either acephate or aldicarb, may have slowed this development further.

When we restricted both carcinogens and potential groundwater contaminators, the effect on return per hectare was approximately equal to the effect due to the elimination of carcinogens alone. Thus in these restricted systems, leafspot control appeared to be the dominant limiting factor. Interestingly, in the non-restrictive pesticide input systems, outbreaks of the two-spotted spider mite were more common than in the more restrictive systems (those that restricted carcinogens or the organic system). This is likely due to one or more of the pesticides in these systems reducing the naturally occurring predators and diseases of the mites and conceivably also affecting both the biology of the mite and the plant. Many fungicides and insecticides are known to enhance spider mite outbreaks (Campbell, 1978).

In our study, the hand weeding labor input for all but the "organic" production system averaged $49 to $99/ha. In the organic production system, hand weeding costs ran from $741 to nearly $2471/ha (Table 2). This large labor outlay was only partly offset by a reduction in pesticide costs of approximately $247 in the organic system. In this system we combined bottom plowing, disking and at least two cultivations with hand weeding to control weeds. In general, organic production resulted in yields 10% to 50% lower than the unrestricted production systems (Table 3).

This yield reduction is smaller than that projected by Smith *et al.* (1990) who projected that peanut yields in the Southern Plains of Texas would decline by 72% with the elimination of crop protection chemicals. In their projections, fungicides and insecticides account for 44% of this decline while herbicides would comprise 33%. In our studies, the loss of fungicides resulted in yield declines in the disease susceptible Florunner ranging from 20% in dryland conditions to nearly 50% under irrigation. Declines due to fungicide loss, however, averaged 28% and were not different between irrigated and non-irrigated fields planted to the partially disease resistant Southern Runner.

In our study, as in others, reductions in weed control options increased grass and broadleaf weed pressures resulting in the need for increased cultivations (Bridges *et al.*, 1984; Wilcut, *et al.*, 1987a; Wilcut, *et al.*, 1987b). While increased cultivation has been reported to increase disease incidence of *Rhizoctonia* limb rot (Brenneman and Sumner, 1989; Porter, *et al.*, 1982), we did not observe this relationship in any of our trial plots. The common troublesome weeds for peanut producers in the Southeast include Texas panicum (*Panicum texanum* Buckl.), sicklepod (*Cassia obtusifolia* L.), Florida beggarweed (*Desmodium tortuosum* (Sw.) DC) and pitted morningglory (*Ipomoea lacunosa* L.) (Buchanan *et al.*, 1983). However, in our organic production plots, the most troublesome weeds were Florida pusley (*Richardia scabra* L.) and crabgrass (*Digitaria* spp.), weeds normally easily controlled with a dinitroanaline herbicide.

If the organic production is figured at the same return as the other systems, then an average (over locations) loss to management of $1137 and $731/ha was measured for Florunner and Southern Runner respectively. However, significant premiums are available for this type of production and it is common to find a 100% premium for organic peanuts. Therefore, we calculated a second return for the organic system at $1.65/kg to determine how return per unit of land would compare to the other systems calculated at the lower price. At this higher price, return from the organic production system with Southern Runner exceeded that of the other systems. However, even with the 100% premium the return to the organic Florunner system was lower than that of the other production systems. The lack of foliar and soil-borne disease resistance in Florunner is probably the primary reason for the higher returns with Southern Runner in the organic production system.

Conclusions

Using a preventative management strategy results in additional pesticide inputs which are not balanced with additional crop production. Both Florunner and Southern Runner averaged $180 lower per hectare return when the preventative management program was compared to the non-restrictive IPM program. The use of crop pest scouting in conjunction with an IPM program significantly improved return per hectare.

When non-restrictive IPM programs were compared to IPM systems that eliminate carcinogens, return to management per hectare declined $1010 and $516 for Florunner and Southern Runner, respectively. The exclusion of the fungicide chlorothalonil was the primary reason for this loss in revenue. Southern Runner tended to have higher returns per hectare than Florunner in the systems restricting carcinogens (Table 4).

Elimination of compounds with low relative leaching potentials (likely to leach) had minimal impact on peanut production. All test locations had low nematode pressures. It is likely that these results would have been different had any of the sites had high nematode pressures. However, due to the high cost and marginal effectiveness of nematode treatments some growers are opting to use rotation as their primary method of nematode control. Therefore, the development of cost effective, nematode reducing rotational crops may provide the best long term solution to the nematode problem.

Of all pest management strategies, the organic production strategy had the highest pre-harvest variable costs, due to the high input of hand labor required for weeding. To produce returns similar to an unrestricted IPM system, a premium of 95% for farmer stock peanut would be necessary. These results are similar to those of Smith *et al.* (1990) and Knutson *et al.* (1990) who expected production costs to rise by 2.88 times, translating to a real price increase from $0.68/kg to $1.69/kg. In our study, total variable costs for the organic system were 155% at Plains and 257% at Tifton of the non-restrictive IPM system's variability costs.

Several methods which we did not use, but which may help future organic production studies reduce the high cost of hand weeding, include using a stale seedbed technique, planting into a cover crop which dies or is killed and forms a weed suppressing mat, or changing row patterns and plant populations to achieve a faster canopy cover. Improved disease resistant cultivars would also help by reducing the unit cost of production.

Our economic analyses were made using enterprise budgets and therefore do not reflect other costs associated with the whole farm operation of which a proportion would have to be assigned back to this enterprise. Also not considered in our economic analyses are the externalities, such as the social costs of the use or non-use of these compounds. Such externalities as the availability of additional farm workers, potential costs associated with groundwater cleanup, farm worker and general public health, and potential dietary changes were beyond the scope of this study.

Since the best data available to us still lacked information about the possible classification of many pesticides or their metabolites as either carcinogens or as potential leachers, future information on these compounds are likely to reveal other pesticides which would fall into in one or more of the restricted categories. However, the future development of alternative pesticides and resistant cultivars would have a counter-balancing effect.

Acknowledgments

The authors appreciate the dedication and assistance of Fred Barnes, Dana Cheek, Art Raczynski, Keith Rucker, Melissa Tawzer, Christie Turner, Genia Vickers, Mary Wauchope, the people at the S.W. Branch Station near Plains and at the Gibbs' farm near Tifton. The authors also appreciate the assistance of Michael Berkhead, Don Shurley and Bob Stark for their help with the economic analysis portion of this research.

Literature Cited

1. Bailey, J. E. and S. Spencer. 1982. Feasibility of peanut leafspot forecasting in North Carolina. Proc. Amer. Peanut Res. Educ. Soc. 14:101. (Abstr.)
2. Brannen, P. M. and P. A. Backman. 1992. On-farm evaluation of AU-Pnuts; an expert system for control of leaf spot diseases of peanuts. Proc. Amer. Peanut Res. Educ. Soc. 24:18. (Abstr.)
3. Brenneman, T. B. and D. R. Sumner. 1989. Effects of chemigated and conventionally sprayed tebuconazole and tractor traffic on peanut diseases and pod yields. Plant disease 73:843-846.
4. Bridges, D. C., R. H. Walker, J. A. McGuire, and N. R. Martin. 1984. Efficiency of chemical and mechanical methods for controlling weeds in peanuts (*Arachis hypogaea*). Weed Sci. 32:548-591.
5. Buchanan, G. A., D. S. Murray, and E. W. Hauser. 1983. Weeds and their control in peanuts. pp.206-249. *in* H. E. Pattee and C. T. Young (ed.), Peanut Science and Technology. Am. Peanut Res. Educ. Soc., Yoakum, TX p.206-249.
6. Campbell, W. V. 1978. Effect of Pesticide interactions on the two-spotted spider mite on peanuts. Peanut Sci. 5:83-86.
7. California Certified Organic Farmers. 1991. Certification Handbook. CCOF, P. O. Box 8136, Santa Cruz, CA.
8. Chiteka, Z. A., D. W. Gorbet, D. A. Knauft, F. M. Shokes, T. A. Kucharek, and A. J. Norden. 1987. Components of resistance to late leafspot in peanut (*Arachis hypogaea* L.). Proc. of Amer. Peanut Res. & Ed. Soc. 19:25. (Abstr.)
9. Garren, K. H. and C. R. Jackson. 1973. Peanut diseases, pp. 429-494. *in* Peanuts: Culture and Uses. Amer. Peanut Res. & Educ. Assoc., Stillwater, OK.
10. Gianessi, L. P. and C. Puffer. 1990. Herbicide Use in the United States. Resources for the Future, Washington, DC.
11. Gibbons, R. W. 1979. Groundnut improvement research technology for the semi-arid tropics. ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). pp. 27-37.1980. Proceedings of the International Symposium on Development and Transfer of Technology for Rainfed Agriculture and the SAT Farmer, 28 August-1 September 1979, Patancheru, A. P., India.
12. Gorbet, D. W., A. J. Norden, F. M. Shokes, and D. A. Knauft. 1986. Southern Runner: A new leaf spot resistant peanut variety. Univ. Florida. Agric. Expt. Stn. Cir. S-374, 13p.
13. Hornsby, A. G., T. M. Buttler, E. B. Whitty, F. A. Johnson, R. A. Dunn, and T. A. Kucharek. 1991. Peanuts: Managing pesticides for crop production and water quality protection. IFAS Pest Control Guides Supplement. Circular 994. Florida Cooperative Extension Service. Gainesville, FL.
14. Jackson, C. R. and D. K. Bell. 1969. Diseases of peanut (groundnut) caused by fungi. Univ. Ga. Exp. Sta. Res. Bull. 55. pp. 7-15.
15. Knutson, R.D., C.R. Taylor, J.B. Penson, and E.G. Smith (1990). Economic impacts of reduced chemical usage. College Station, TX: Knutson and Associates.
16. Kucharek, T. A. 1975. Reduction of cercospora leafspots of peanut with crop rotation. Plant Dis. Reptr. 59:822-823.
17. *Les v. EPA*, CA 9, No. 91-70234, 56 Fed. Reg. 7750, 7/8/92.
18. National Academy of Sciences, National Research Council, Board on Agriculture. 1987. Regulating pesticides in food: the Delaney paradox. National Academy Press, Washington, DC.
19. National Academy of Sciences, National Research Council, Board on Agriculture. 1993. Pesticides in the diets of infants and children. National Academy Press, Washington, DC.
20. National Peanut Council. 1991. Environmental Affairs Committee Report. National Peanut Council, Alexandria, VA.
21. Phipps, P. M. 1982. Virginia growers to test leafspot advisories in 1981. Proc. Amer. Peanut Res. Educ. Soc. 13:113. (Abstr.)
22. Phipps, P. M., and N. L. Powell. 1984. Criteria for utilization of peanut leafspot advisories in Virginia. Phytopathology 74:1189-1193.
23. Phipps, P. M., D. A. Herbert, J. W. Wilcut, C. W. Swann, G. G. Gallimore, and D. B. Taylor. 1990. Impact of chemical-use restrictions on disease, weed and insect management in peanuts. Proc. Amer. Peanut Res. Educ. Assoc. p. 43 (Abstr.)
24. Porter, D. M., D. H. Smith, and R. Rodriguez-Kabana. 1982. Peanut Plant diseases. pp.326-410. *in* H. E. Pattee and C. T. Young, (eds;) Peanut Science and Technology. Am. Peanut Res. Educ. Soc., Yoakum, TX.
25. SAS Institute Inc. SAS/STAT user's guide, version 6, Fourth Edition,

Volume 1, Cary, NC: SAS Institute Inc., 1989. 943 PP.
26. Smith, E.G., R.D. Knutson, C.R. Taylor, and J.B. Penson (1990). Impacts of chemical use reduction on crop yields and costs. Agricultural and Food Policy Center, Department of Agricultural Economics, Texas A&M University System, College Station, TX.
27. Smith, D. H. and R. H. Littrell. 1980. Management of peanut foliar diseases with fungicides. Plant Disease 64:356-361.
28. USEPA/OPP RFD Tracking Report, January 6, 1993.
29. Wilcut, J. W., G. R. Wehtje, and M. G. Patterson. 1987a. Economic assessment of weed control systems for peanuts (*Arachis hypogaea*). Weed Sci. 35:433-437.
30. Wilcut, J. W., G. R. Wehtje, and R. H. Walker. 1987b. Economics of weed control in peanuts (*Arachis hypogaea*) with herbicides and cultivations. Weed Sci. 35:711-715.
31. Williams, E. J. and J. S. Drexler. 1981. A non-destructive method for determining peanut pod maturity. Peanut Sci. 8:124-141.

Accepted July 31, 1993

Peanut Science (1993) 20:124-126