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Developing and Implementing IPM Strategies to Assist Farmers: An Industry Approach

Since World War II, pesticides have played a major role in the effort to ensure an abundance of food at an affordable price. At present, however, public perception that residues of synthetic pesticides create food safety concerns and mounting pressure from special interest groups, retailers, and others to reduce the use of pesticides are creating a serious dilemma for the food processing industry. The critical issue currently facing the industry is how to control pests and diseases with less use of pesticides without affecting the wholesomeness and aesthetics of the food supply. The steps taken by Campbell Soup Company are representative of a widespread shift in corporate thinking. Rather than merely complying with end-of-the-pipeline environmental regulations, the company adopted a "total system" approach to pesticide management that covers all areas of pest control, ranging from cooperative efforts with its growers to analytical surveillance of ingredients and products in the laboratory. The implementation of integrated pest management (IPM) among its growers as a biologically and environmentally sound approach to pest control is supported and promoted as a means to significantly reduce the amount of synthetic pesticides applied to a crop. In addition, Campbell Soup Company set a corporate goal to reduce the number of synthetic pesticide applications per season on crops grown for the company by 50% by the end of 1994.

IPM Approach

Campbell Soup Company employs in-house IPM specialists and IPM practitioners who conduct field and laboratory research as well as develop and implement IPM programs. Also, IPM specialists collaborate with and provide grants to universities doing research to develop IPM strategies that reduce the use of pesticides. IPM strategies examined include risk assessment, forecasting and monitoring, use of resistant cultivars, use of bioinsecticides, disruption of insect mating, release of natural enemies, and judicious use of pesticides (1).

IPM programs have been successfully developed and implemented for processing tomatoes, celery, carrots, mushrooms, and poultry (1). Campbell's IPM programs have been developed to raise farmers' awareness of alternative pest control strategies and also to be conducted in partnership with its growers. When a new IPM program is introduced, IPM practitioners split the grower's field and implement the IPM program on one half of the field while the grower practices conventional pest management on the other half. At the end of the season, yield, quality, and cost of production are compared and the grower draws his own conclusions. During this introductory period of the IPM program, Campbell Soup Company assumes all the financial risks on the IPM half of the field should yield quality and/or quantity fall below expectations. The demonstration plot process is repeated for two consecutive years. If the IPM program is successful, the grower is expected to assume full responsibility and implement the IPM program(s) on his entire hectarage.

IPM specialists and IPM practitioners continue to refine the programs and interact with the grower as consultants at no cost to the grower. The company's involvement and encouragement on the use of IPM have aided the acceptance and enhanced the adoption of IPM practices among its growers. In addition, farmers have come to realize that IPM programs provide the tools by which they can increase revenues and lower risk while reducing pesticide use.

IPM Programs

Each year Campbell Soup Company contracts with growers for approximately 12,141 ha of processing tomatoes (*Lycopersicon esculentum* Mill.) in California, Ohio, and Mexico. Carrots (*Daucus carota* L. var. *sativa* Hoffm.) are grown mainly in California, Texas, Ohio, and New Jersey, while celery (*Apium graveolens* L. var. *dulce* (Mill.) Pers.) is grown in California, Michigan, and Florida. The contracts specify delivery dates, along with the specific cultivar, quality expectations, and a list of approved pesticides that can be used if needed. Planting is staggered through the planting season to achieve an orderly harvesting schedule with only a certain proportion of the crop coming to the processing plant at any point in time. Today, all carrot and celery production, all processing tomato production in Mexico, and 95% of tomato production in Ohio are under IPM programs developed by Campbell Research and Development and Campbell Agricultural Operations (1). Most Campbell Soup Company tomato contract growers in California practice some form of IPM. In 1992, the company launched an aggressive program to encourage contract growers in California to further adopt IPM practices developed by the University of California (11) and Campbell Soup Company (1).

All company IPM programs involve three interrelated components: cultural practices, monitoring, and treatment. The most important cultural practices include crop rotation and field selection to minimize problems with weeds, virus diseases, and root rots. Field sanitation to eliminate weed populations prevents potential migration and infestation of pests and viruses. Tillage operations and herbicides are selected on the basis of current and past field conditions to provide the appropriately shaped beds. Cultivars are selected on the basis of their resistance to fungal, bacterial, and nematode diseases (4). For example, all processing tomato cultivars produced by contract growers are resistant to races 1 and 2 of Fusarium wilt (caused by *F. oxysporum* Schlechtend.:Fr. f. sp. *lycopersici* (Sacc.) W.C. Snyder & H.N. Hans.) and to race 1 of Verticillium wilt (caused by *V. dahliae* Kleb.). In California, in early-season tomato plantings where the environmental conditions are conducive to the development of bacterial speck disease (caused by *Pseudomonas syringae* pv. *tomato* (Okabe)

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Young et al), cultivars such as CXD 166 and CXD 171, which carry resistance to the pathogen (4), are planted to eliminate the need for pesticide applications. Similarly, when a contract grower plants in a field with a history of root-knot nematode (*Meloidogyne* spp.), cultivars such as CXD 154 and CXD 151 with resistance to root-knot nematode (4) are planted, thus eliminating the need for soil fumigation.

The second essential component of the IPM program is monitoring for pest populations. IPM personnel carefully scout grower fields periodically throughout the season. For instance, as part of the service provided by Campbell Soup Company in Mexico and Ohio, the grower's crop is monitored once a week for insects and plant diseases, and the grower is informed about insect species found, their stage of growth, their distribution in the field, and the size of the population. The IPM specialists identify the diseases present, quantify severity, and pinpoint new disease activity and spread. An important aspect of the Campbell Mexico IPM program is for IPM practitioners to work closely with the growers to eliminate sources and reservoirs of diseases in and around their fields and to help the grower understand how diseases develop and spread. The IPM practitioner visits each grower and holds one-on-one meetings to explain the sequence of the IPM strategies to be implemented (1) and addresses any concern the contract grower may have. In addition, sex pheromone traps (10) are routinely used to survey and detect the presence of insects as well as to monitor and control adult insect populations.

The third component of the IPM program is treatment. When it is determined, through monitoring and scouting, that pest populations have reached the level at which they will cause economic damage, the grower is advised to use various control techniques. Where appropriate, the grower is encouraged to apply selective or biorational pesticides such as *Bacillus thuringiensis* Berliner or related materials that do not harm beneficial insects (8). In addition, parasitic wasps (*Trichogramma pretiosum* Riley) are released to augment natural control of fruitworm eggs in Mexico (1).

Fig. 1. The computerized air temperature and leaf wetness recorder (Model DP 223, Omnidata International, Inc., Logan, UT) used in the TOM-CAST forecasting system.

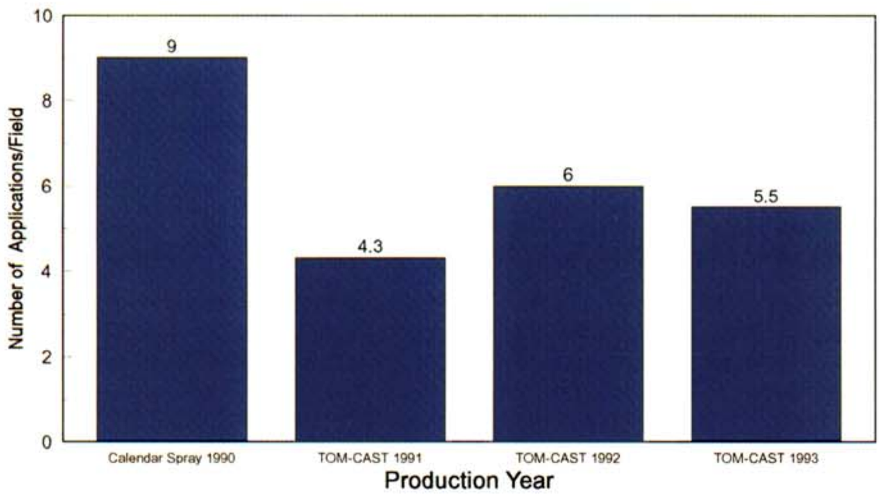

Fig. 2. Impact of the TOM-CAST forecasting system on fungicide use in processing tomatoes grown for Campbell Soup Company in Ohio.

Table 1. Costs of TOM-CAST integrated pest management and calendar spray management of processing tomatoes grown for Campbell Soup Company by 39 farmers on a total of 1,497 ha in Ohio

		Fungicide applications		
Year	System	Av. no.	Cost/ha ($)	Total ($)
1990	Calendar spray	9.0	389	582,333
1991	TOM-CAST IPM	4.3	186	278,442
1992	TOM-CAST IPM	6.0	260	389,220
1993	TOM-CAST IPM	5.5	238	356,286

Disease Management

The predominant diseases of concern on processing tomatoes are anthrachnose fruit rot (caused by *Colletotrichum coccodes* (Wallr.) S.J. Hughes) in Ohio, black mold (caused by *Alternaria alternata* (Fr.:Fr.) Keissl.) in California, and late blight (caused by *Phytophthora infestans* (Mont.) de Bary) and geminivirus infections in Mexico. Septoria late blight (caused by *S. apiicola* Speg.) and Alternaria leaf blight (caused by *A. dauci* (Kühn) Groves & Skolko) are diseases of concern on celery and carrots, respectively. The IPM program for managing these diseases is based on the prediction of disease development under existing environmental conditions followed by the timely application of fungicides.

In 1989, Campbell Soup Company adopted the TOM-CAST computerized disease forecasting system for its growers in Ohio (6). The company has aggressively implemented the use of the TOM-CAST system on a commercial scale and has obtained 95% grower participation. The program is operated by dividing the tomato and carrot production area into nine zones, with each zone having a 10-mile radius. A temperature and leaf wetness recorder (Model DP 223, Omnidata International, Inc., Logan, Utah) is placed in each zone to obtain hourly air temperature and leaf wetness values (Fig. 1). Disease severity values (DSVs) based on environmental data are calculated daily for each zone, and cumulative DSVs are recorded on a toll-free telephone line for grower access. The initial fungicide spray uses 35 DSVs. If 35 DSVs have not been accumulated by 5 July, the first protective fungicide application is made on that date; subsequent applications require accumulation of 20 DSVs.

The number of fungicide applications has dropped dramatically since the TOM-CAST forecasting system was implemented (Fig. 2). Spray records for the 1991 growing season for approximately 1,497 ha showed an average of 4.3 fungicide applications per hectare for 39 growers of processing tomatoes practicing IPM, compared with an average of 9.0 fungicide applications per hectare in 1990 for growers using the calendar spray system. The actual savings with use of the TOM-CAST IPM system was $304,325, or approximately $203/ha (Table 1). In 1993, the savings with the use of 5.5 fungicide applications was $226,625, or approximately $151/ha and $2.53/t of tomatoes. Similarly, in 1993, the carrot growers in Michigan and Ohio used an average of 0.8 insecticide applications per hectare, representing a 75.8% reduction in synthetic insecticide use from the 1990 growing season, when IPM was not extensively practiced (Fig. 3). Much of the cost reductions resulted from improved timing of pesticide use, which allowed application of fungicides only when necessary and often eliminated the need for repeat applications. At present, the TOM-CAST system runs until late September to provide the DSVs for both processing tomato and carrot growers.

In 1992, the TOM-CAST system was established for Septoria late blight on celery and black mold on processing tomatoes in California. Pesticide applications on celery have often been based solely on the stage of plant development, not on the presence of diseases or insects. In seasons with low disease and/or insect pressure, this management strategy results in unnecessary applications of chemicals. Following the implementation of the TOM-CAST system and monitoring for insects, celery growers in California were able to save 12 pesticide applications per season in 1992 and nine in 1993 (Fig. 4). Similarly, by using the TOM-CAST system to predict black mold in processing tomatoes, as well as tolerant cultivars in locations where the disease was likely to develop (Campbell Soup Company, *unpublished*), nine growers who participated in the IPM program were able to use 1.1 fewer sprays per field than growers who sprayed on a calendar basis (Table 2). The average percent fruit with black mold symptoms was 1.9 for growers in the IPM program and 2.4 for growers who sprayed on a calendar basis (Table 2); these values, however, are not statistically different ($P = 0.05$). The actual cost savings for growers in the IPM program was $82/ha. Celery and tomato growers continue to monitor for insects and use the TOM-CAST system until harvest.

Management of late blight in Mexico. Campbell Soup Company's processing tomato operations are located in the Del Fuerte Valley in the northern part of the state of Sinaloa. The processing tomato season starts with planting in September and extends to final harvest in June. The northern Sinaloa area is considered "dry desert," with an average rainfall of 300–350 mm per year and temperatures ranging from 0 to 45 C and averaging 25.5 C annually. During the winter months, temperature averages 19 C and rainfall, 50 mm.

Until 1990, typical processing tomato production practices in northern Sinaloa included up to 12 fungicide sprays to control late blight disease (Campbell Soup Company, *unpublished*). The intensity of fungicide applications and the use of metalaxyl gave rise to substantial resistance in the fungal populations (3). In 1992, a potato disease management (PDM) software (7) was adopted to im-

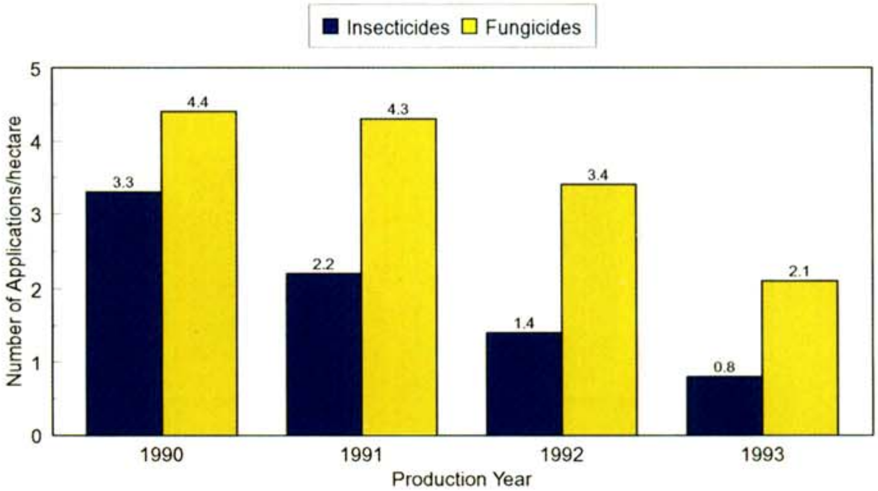

Fig. 3. Impact of IPM programs on pesticide use in carrots grown for Campbell Soup Company in Michigan and Ohio.

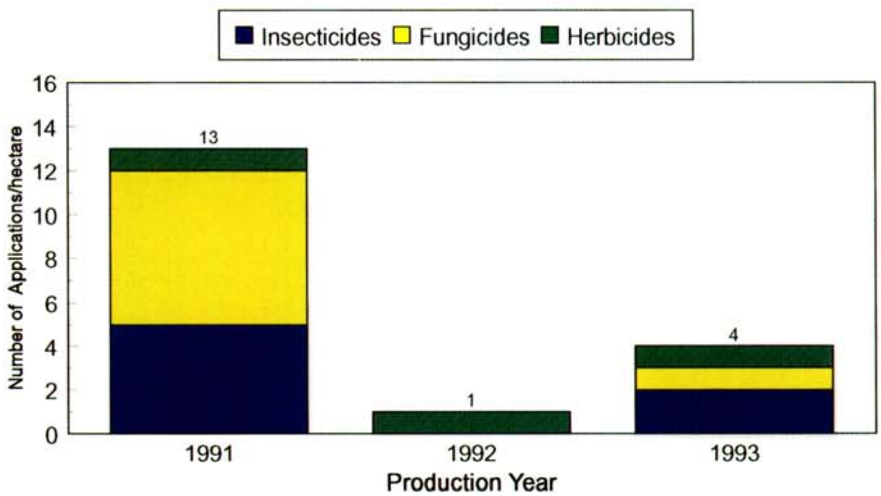

Fig. 4. Impact of IPM programs on use of synthetic insecticides and fungicides in celery grown for Campbell Soup Company in California.

Table 2. Management of black mold disease in nine processing tomato fields in California during the 1993 growing season

Management system	No. of fungicide applications/field[x]	Percent fruit with black mold	Cost/ha[y] ($)
TOM-CAST	0.6	1.9 a[z]	45
Calendar spray	1.7	2.4 a	127

[x] Means of nine fields.
[y] Fungicide plus application cost.
[z] Values followed by the same letter are not statistically significant ($P = 0.05$) according to Duncan's multiple range test.

plement a forecasting system to reduce the number of fungicide applications. This disease prediction software allows the grower to initiate the first protective fungicide application when environmental conditions are optimal for disease development and to continue applications at 10-day intervals thereafter. Although very effective in initiating sprays, the PDM system may result in unnecessary pesticide use because of the calendar-scheduled applications following the first spray. The current approach is to use the PDM software for determining the initial fungicide application, then switch to the TOM-CAST system (6) and use 20 DSVs for subsequent applications. Adoption of a combination of PDM and TOM-CAST forecasting systems has improved timing of fungicide applications and control of late blight and has lowered cost (3). During the 1992–1993 crop season, implementing the PDM/TOM-CAST system reduced the number of fungicide applications by 54.4%, at a cost savings of approximately $168/ha, compared with a conventional 10-day calendar spray program (Fig. 5). The cost savings were due to improved timing of fungicide use and elimination of unnecessary applications. The PDM/TOM-CAST forecasting system is initiated at the beginning of planting and discontinued in late April, when environmental conditions do not favor development of late blight.

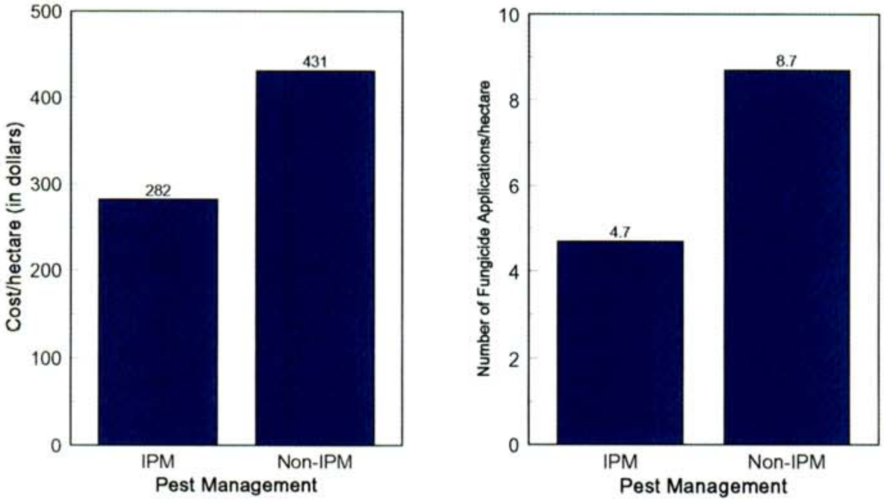

Fig. 5. Average cost and number of fungicide sprays used to control late blight disease in processing tomatoes by IPM and non-IPM growers in northern Sinaloa, Mexico, during the 1992–1993 growing season.

Table 3. Relative risk[z] and incidence of geminiviruses in processing tomatoes grown for Campbell Soup Company in northern Sinaloa, Mexico, during the 1992–1993 season

	Early planting time (Sept.–Oct.)		Intermediate planting time (Nov.–Dec.)	
Location	**Relative risk**	**Incidence (%)**	**Relative risk**	**Incidence (%)**
Los Mochis	4.4	17.4	4.6	2.2
Guasave	2.9	4.4	3.3	0.3
Bamoa	1.9	0.3	1.9	0.1

[z] Fields were ranked on a scale of 1–25 for relative risk of virus infection on the basis of condition of nearby ditches, roadsides, unplanted areas, and crops.

Virus abatement in Mexico. Geminiviruses are a serious problem on processing tomatoes in northern Sinaloa, and disease levels are affected by the specific date of planting in the fall (5; M. R. Nelson et al, *unpublished*). The geminiviruses are transmitted by whiteflies (*Bemisia tabaci* (Gennadius)), which are associated with the local soybean crop and which move from the soybeans when the crop is harvested in August and October. Whitefly populations are highest during early tomato planting (September) and decrease to low levels by the late plantings (after mid-October). During 1988–1990, the University of Arizona assessed the viruses present and their impact on production of processing tomatoes in the Del Fuerte valley (2,5). The information obtained led to the building of an agricultural geographic information system (GIS) database for that region, and the GIS system was used to develop a sustainable virus abatement program for Campbell Soup Company (5; M. R. Nelson et al, *unpublished*). This abatement program is based on estimating the risk of virus infection for individual fields as a means of selecting fields for early tomato planting that are at least risk for virus infection (Table 3). Fields with a high risk of virus infection are planted after the migrating insect vector populations have dropped to low levels. With this program, risk modification is also possible. For example, the risk for a field with a high risk for virus infection because of the presence of weeds with obvious virus symptoms can be reduced by removing the weeds from within the field and around the borders and canals. This strategy has provided the tools and technical input to establish a long-term plant virus management program for tomato production in northern Sinaloa. Since this strategy was adopted, use of pesticides to control virus vectors has been completely eliminated.

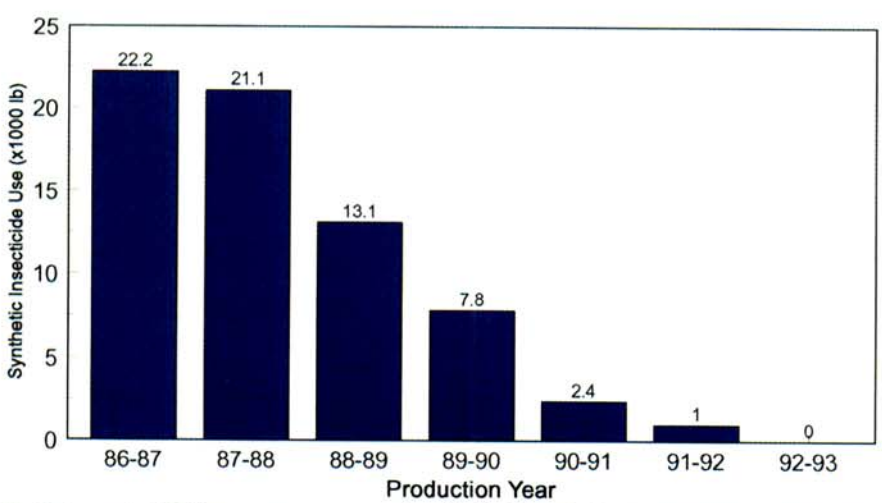

Fig. 6. Impact of IPM programs on use of synthetic insecticides in processing tomatoes grown for Campbell Soup Company in northern Sinaloa, Mexico.

Insect Control Programs

In Mexico. The prominent insect pests affecting processing tomatoes in northern Sinaloa are tomato pinworms (*Keiferia lycopersicella* (Walsingham)), tomato fruitworms (*Helicoverpa zea* (Boddie)), beet armyworms (*Spodoptera* *exigua* (Hübner)), yellowstriped armyworms (*S. ornithogalli* (Guenée)), and stink bugs (*Euschistus conspersus* Uhler). Traditionally, these lepidopterous pests have been controlled with up to 40 applications per crop of broad-spectrum insecticides (9). This approach was costly, resulted in the buildup of resistance in the pest populations, had an adverse effect on the nontargeted beneficial insects, and led to detectable levels of pesticide residues. In 1986, Campbell Soup Company implemented an IPM program that provided a complete management strategy for the pest complex rather than a short-term solution to a single problem (9). The program goals were to use: 1) monitoring systems to increase the lead time for control decisions and actions; 2) when possible, biorational insecticides to encourage the buildup of natural enemies; and 3) a minimum number of pesticide applications per crop. The IPM program has two objectives: 1) treat only when insect damage is projected to exceed the cost of control and 2) determine the most effective timing for pesticide applications. An IPM sampling method for these pests involves using pheromone traps to determine the populations of the adult insects, using leaf samples and whole plants to determine the presence of eggs and/or larvae, and measuring fruit damage. The three components of the insect management strategy, used singly or in combination, are disruption of mating, application of microbial pesticides, and release of natural enemies. Conventional pesticides are replaced, for the most part, by biological and cultural alternatives.

Mating disruption is used against tomato pinworm when male moth populations exceed two to five adults per trap per night. Female pheromones in hollow fibers or in plastic dispensers are applied to the entire field if pinworm pressure is high (more than five adults per trap per night) or to alternate rows of the first 20 rows of the field ("field ringing") if pressure is less than five adults per trap per night. When the threshold exceeds 0.5 larvae per plant, a microbial insecticide such as avermectin is applied, but only to infested areas. *Bacillus thuringiensis* toxins are applied only when armyworm populations exceed a threshold of 0.5 larvae per plant. Microbial pesticides are also used to suppress tomato fruitworm when thresholds exceed 16 viable eggs per 100 randomly picked leaves. Additional control of the tomato fruitworm pest is achieved with six weekly releases of approximately 750,000 eggs per hectare (1) of the wasp parasite *T. pretiosum*. The parasitic wasps are reared by Campbell Soup Company and made available at a nominal cost to its growers as pupae within *Sitotroga* sp. eggs glued on 2.5 × 2.5 cm cards (9). The IPM practitioner and/or the grower places the *T. pretiosum* egg masses in the plant canopy thoroughout the field.

One IPM specialist and four IPM practitioners monitor and make recommendations for approximately 1,800 ha of processing tomatoes. At least once a week, the IPM practitioners monitor every assigned field for tomato pinworm (adults, eggs, larvae, and damaged fruit), beet armyworm (egg masses, larvae, and damaged fruit), tomato fruitworm (eggs and damaged fruit), and stink bugs

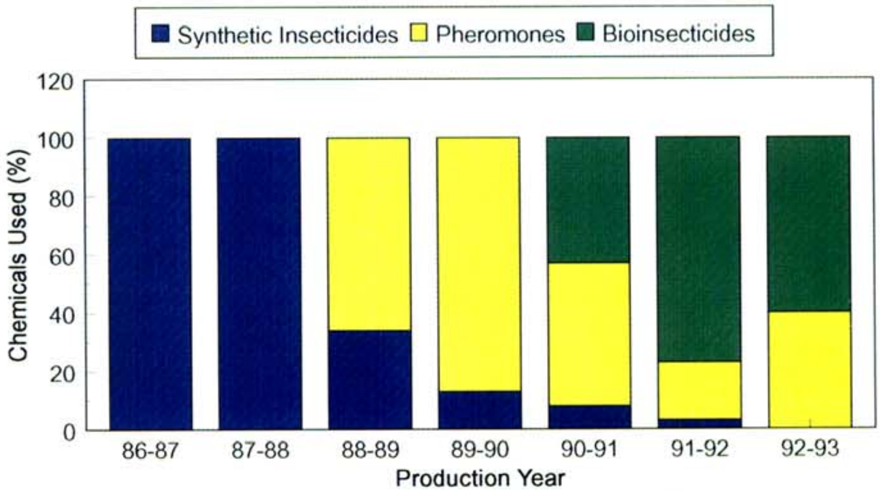

Fig. 7. Transition from synthetic insecticides to biorational insecticides in processing tomatoes grown for Campbell Soup Company in northern Sinaloa, Mexico.

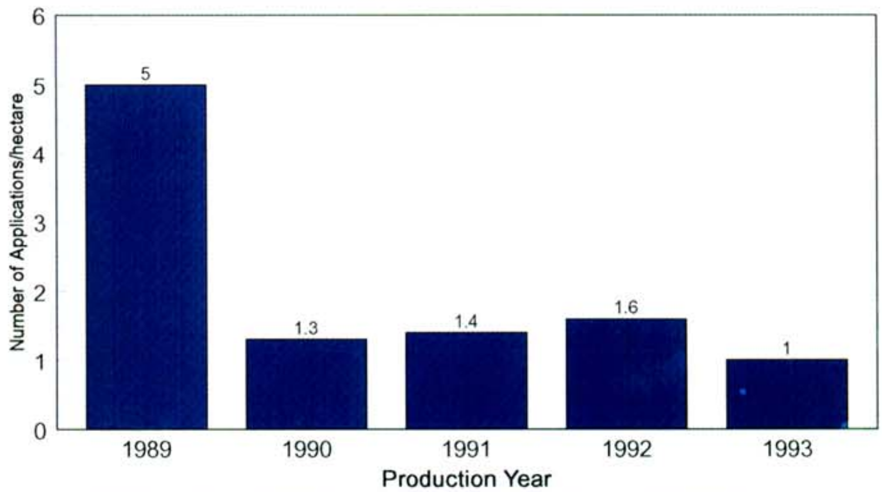

Fig. 8. Impact of IPM programs on synthetic insecticide use in processing tomatoes grown for Campbell Soup Company in Ohio.

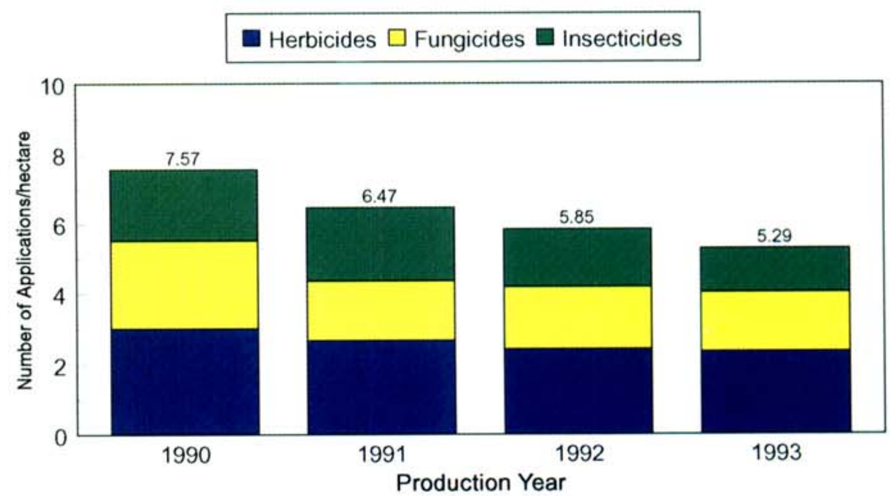

Fig. 9. Impact of IPM programs on pesticide applications in processing tomatoes grown for Campbell Soup Company in California.

(nymphs and adults). The IPM practitioners also submit egg samples and larvae of the pests to determine the rates of natural parasitism (1). This information is critical to deciding what control action, if any, should be taken in the field.

Adoption of the insect IPM program has reduced the use of synthetic insecticides in northern Sinaloa (Figs. 6 and 7) and has also minimized the risk of crop damage and yield loss caused by insects. Fields in the 1991–1992 IPM program had 66% less tomato pinworm and 10% less tomato fruitworm damage than fields not in the program (*data not shown*). Synthetic pesticide use was 96% less when the sampling method was used. During the 1992–1993 crop season, no synthetic insecticides were used by Campbell Soup Company growers to control insect pests (Fig. 6), and the growers cumulatively saved approximately $252,000 ($189/ha) in insecticide and application costs compared with the 1988–1989 crop season, when no IPM strategies were used.

In California and Ohio. The insect IPM programs for Ohio and California are similar to that for Mexico. At these locations, however, control strategies are based on the judicious use of synthetic insecticides through programs of field scouting and determination of action thresholds. In 1990 and 1991, Ohio growers participating in the Campbell IPM program made an average of 1.3 pesticide applications per hectare, compared with five applications by nonparticipants (Fig. 8), with resultant savings of $95,500 ($64/ha). Campbell Soup Company has just begun its IPM program in California. Even so, overall pesticide use has declined more than 30% since some IPM practices were adopted (Fig. 9).

Meeting the Goal

After 4 years of development and implementation of IPM strategies, Campbell Soup Company has attained and surpassed its corporate goal of reducing pesticide applications by 50% on crops grown for the company. Overall, tomato, carrot, and celery growers have reduced their pesticide applications per growing season by more than 59%, with reductions ranging from 30% in California to 100% in Mexico. Reduced pesticide use not only lowers production costs per hectare but also increases the effectiveness of pesticides by lessening the chances of resistance developing. However, growers will accept new pest management approaches only if they have the necessary information to make decisions about the economic implications of the new strategies. Campbell Soup Company's IPM strategies have proved to be cost-effective without sacrificing crop yield or quality. Additionally, the strategies meet the requirements of the consumer with respect to enhanced food safety and a cleaner environment.

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