Pest Break Strips for Biological Control of Insect Pests in Nature Farming: A New Perspective for Integrated Pest Management

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Abstract

The Naturfarm, located near Lompoc, California comprises about 75 tillable acres of cropland and is certified as an organic vegetable farm by the California Certified Organic Farmers Association (CCOF). The mission of the Naturfarm is to promote the art and science of Kyusei Nature Farming for a sustainable agriculture and environment through organic and biological (i.e., non-chemical) methods. One such method that was evaluated for the biological control of insect pests at the Naturfarm is pest break strips. A five-year (1989-1994) study of this technology was funded by the California Energy Commission (CEC) known as the “Naturfarm Conversion Project”. Pest break strips are actually a version of strip-cropping in which the break strips, consisting of an alfalfa-clover mixture are strip-intercropped with organically-grown vegetables. The CEC/Naturfarm study focused on reducing the risk of transition from chemical-based, conventional farming to biological-based, organic or nature farming systems. Whole farm economic and ecological performance was monitored during the study and the energy requirements for tillage, soil fertility and pest control for conventional and nature farming systems were compared. The results of this study have shown that pest break strips provide a highly effective and practical means for controlling insect pests in nature farming. This technology has now become an essential integrated pest management (IPM) strategy at the Naturfarm.

Historical Background

The pioneering efforts of Schlinger and Dietrick (1960) and Stern et al. (1964, 1967) demonstrated that the population dynamics of beneficial insects and insect pests could be manipulated in pest break strips by strip-cutting. This practice consists of cutting only half of the pest break strip at any one time. This allows half the pest break strip to grow to the taller flowering stage prior to cutting, while the other half is in a low-growing vegetative state. The young, lush uncut strips make excellent trap crops, catching incoming pests from cut strips, harvested crops and migrations. Beneficial insects are several-fold more numerous when pest break strips are strip-cut compared with simply cutting to a uniform height.

Schlinger and Dietrick (1960) counted 400 percent more natural predator insects per acre in strip-cut alfalfa, compared with cutting and harvesting the whole stand. When the cut alfalfa is sheet-composted rather than removed from the field, an expanded food chain of organisms supports an even more diverse and abundant supply of beneficial arthropods. The increased numbers of insect predators and parasites generated in strip-cut alfalfa as reported by Schlinger and Dietrick (1960) are shown in Table 1.

Table 1: Comparison of Number of Beneficial Arthropods in Strip-Cut Alfalfa (Schlinger and Dietrick, 1960).

Beneficial Arthropod	Strip-Cut (no./acre)	Full-Cut (no./acre)	Increase from Strip-Cut (%)
Predatory spiders	1,000,000	100,000	1,000
Parasitic wasps	287,000	71,750	400
Big eyed bugs	401,000	200,500	200
Lady beetle (adults)	200,000	50,000	400
Lady beetle (Larvae)	232,000	11,000	2,000

The initial design of the pest break strip system at the Naturfarm was developed by the farm management in consultation with Everett J. Dietrick, a widely-recognized authority on biological control of insect pests and IPM strategies (Drlik, 1995). Dietrick served as the Naturfarm's pest control advisor (PCA) on the CEC/Naturfarm Conversion Project. The Naturfarm's pest break strips were designed to make this type of biological control a more permanent feature of vegetable farms. An essential part of making this system more permanent and effective is the use of strip-cut alfalfa.

Design Establishment and Benefits of Pest Break Strips

Design and Layout

The Naturfarm uses five to ten percent of the land base of farmable acres for pest break strips. The initial Naturfarm pest break strips were five to seven beds wide (80-inch bed width) at 350 foot intervals across the farm. To be effective, pest break strips should be located at regular intervals within the production area, not just as border strips at the field boundaries. With proper management and care, pest break strips become on-farm insectaries producing crops of beneficial species to control pests. When located directly in the production area, a pest break strip helps distribute beneficial species throughout the cash crop. When located at the border of production fields, valuable biological control agents may be tempted to migrate out of the field and away from target pests.

In areas with a prevailing wind factor, it helps to layout pest break strips perpendicular to the prevailing wind direction. This orientation maximizes the pest-trapping effects and facilitates distribution of the beneficial arthropods to the crop. Intervals between strips should be from 350 to 700 feet. For the Naturfarm, with a strong prevailing westerly wind, 350 feet has proven to be an effective interval for locating pest break strips as intercrops to organic vegetable crops.

Pest break strips should be designed with strip-cutting and irrigation management in mind from the very beginning. Bed number, layout and irrigation can be coordinated for efficient management. Using odd numbers of beds, for example, means inefficient mowing operations since an extra pass to the far end of the field is inevitable with this layout. This can be overcome if pest break strips are managed in pairs and if there are even numbers of strips in fields. A better choice is to configure pest break strips in pairs of beds at the start. Four beds at 72-80 inch centers is a recommended minimum area for an effective pest break strip that is efficient and easy to manage.

Plant Selection and Blends

The plant species composition of three blends tested at the Naturfarm from 1990 to 1995 for their use in pest break strips are reported in Table 2. In 1990, the first pest break strips were planted to a mixture of alfalfa, strawbeny clover and orchardgrass, and referred to as Naturfarm Blend No. 1. We then switched to a commercially available insectary blend in 1992 that was supposedly formulated to attract beneficial insects . However, in 1994 we selected a blend of alfalfa and four clovers, which is referred to as Naturfarm Blend No. 2. We continue to use this blend because it is well-adapted to agroecological conditions at the Naturfam.

The choice of plant species and blends for pest break strips is somewhat arbitrary, pro-vided that alfalfa is the predominant component of the mixture. Alfalfa attracts the most insect pests and their predators and parasites. It is the most amenable plant species for strip-cutting. Perennial species are the most useful in pest break strips. Perennials persist year round and begin growing early in spring when most needed. Annual and biennial species do not adapt well to the practice of regular mowing. Also, the ability of many annual and biennial species to attract beneficial insects is usually short-1ived and may not last for the growing season. Annual and biennial plants are most attractive to beneficial species as nectar and pollen sources when they are in flower. Insectary blends are more useful as border strips and trap crops. Unfortunately, trap crops can also have negative impacts. At the Naturfarm, use of an insectary blend that included annual weed species such as black mustard and wild radish attracted large numbers of flea beetles. At first, the result was beneficial to nearby broccoli crops. However, as the radish and mustard completed their life cycle and went to flower, flea beetles migrated in great numbers to the broccoli crop causing considerable damage and economic loss.

Table 2: Plant Species Composition of Three Blends Tested in Pest Break Strips at the Naturfarm During 1990-1995.

Blend	Species	Composition (%)
Original Naturfarm Blend No. 1 (1990-1992)	Alfalfa	70
	Pasture grass	20
	Strawberry clover	10
Beneficial Blend (Forumlated by Lohse Mills) (1992-1993)	Cereal rye	15
	Barley	18
	Karridale subclover	18
	Common vetch	10
	Yellow sweet clover	10
	Crimson clover	9
	Alfalfa	5
	Mustard	5
	Wildflowers	5
	Herbs, various	2.5
	Vegetable, various	2.5
Naturfarm Blend No.2 (1994-1995)	Alfalfa	60
	Dutch white clover	10
	Strawberry clover	10
	Berseem clover	10
	Crimson clover	10

All blends were mixed at Lohse Mills, P.O. Box 168, Atrois, CA 95913.

Establishment

Establishment Whenever possible, pest break strips should be planted well ahead of when they are needed for pest control. Alfalfa is usually planted either in the early spring or early fall. For Naturfarm Blend No. 2, it has been our experience that early fall is the best time for planting. Strips can be planted with a modified grain drill, a brillion, or a specialty planter, depending on the mix and available equipment. At the Naturfarm, the first plantings of pest break strips were broadcast seeded using a rotary spreader. Later plantings were drilled with a 6-foot wide Schmeizer Vineyard Drill (Great Plains, Mfg.), which provided more even-spacing than broadcast seedings.

Insect population assessments during the CEC/Naturfam study showed that within nine to twelve months after planting the pest break strips, the vast complex of beneficial predators and parasites of insect pests, known to inhabit strip-cut alfalfa, were well-established in the pest break strips (Schlinger and Dietrick, 1960; Stern et al., 1964).

Economic Value and Benefit

Economic Value and Benefit The CEC/Naturfarm study found that the economic value of pest control agents produced in the pest break strips exceeds the lost value of potential cash crops that could have been raised in the same area. Also, the cost of growing and managing pest break strips is much less than the cost of conventional control of pests with chemical sprays (Dietrick et al., 1995).

The economic value and benefit of pest break strips is reported in Table 3. It is important to note that this is only a partial list of the many important biological control agents produced in a properly managed and well-functioning pest break strip. This list is based on the data of Schlinger and Dietrick (1960) for strip-cut alfalfa and recent prices (where available) from commercial insectaries. The dollar value of the full complement of biological control agents produced in the pest break strips is much more than the total listed in Table 3. Many of these biological control species simply cannot be produced in commercial insectaries and are only available from natural sources. Additional dollar value must be assigned to the savings for eliminating chemical pest control and for the added premium price paid for organic crops that can be successfully produced using pest break strips as the principal insect pest management strategy.

Table 3: Value in Dollars Per Acre of Some Beneficial Arthropods Produced in Pest Break Strips at the Naturfarm.

Group or Species	Population/Acre of Pest Break Strip (no.)	Individual Cost ($US)	Value Per Acre ($US)
Lady beetle (adults)	200,000	0.0006	125
Lady beetle (larvae)			
Lacewing larvae	232,000	0.025	5,820
Spiders			
Big-eyed bugs	206,000	0.003	5,071
Parasitic wasps	1,000,000	0.003	3,000
	401,000	0.003	1,203
	287,000	0.007	2,009
Total numbers and value/acre	2,326,000	Aver 0.007	17,208

Cost are based on a range of 1995 California insectary prices for beneficial arthropods.

Management and Maintenance of Pest Break Strips

Mowing and Strip-Cutting

At the Naturfarm, the alfalfa-based pest break strips are mowed at regular intervals. One of the key indicators that a stand is ready for mowing is the onset of flowering of plants in the strip. Some flowering is desirable, as this helps attract certain beneficial species. However, once seed is set and reaches the milky stage of development, pest species such as *Lygus* and squash bugs and others are attracted in great numbers. Furthermore, there are substances in the milky stage of seed development that induce these pests to reproduce. Therefore, this condition is to be avoided in managing the mowing schedule of pest break strips. Usually, if half the strip is cut when flowers in alfalfa first start to appear, the second half can be cut in 10 to 14 days before too many flowers reach the milky stage of seed production.

The first mowing of a new pest break strip will be determined by several factors including the amount of competition with weeds and the degree of maturity of the alfalfa and other desirable plants. In newly planted strips, mowing may be necessary on occasion to allow the alfalfa to dominate the weeds. Certainly, it is recommended to mow the strips before the weeds set seed. After the pest break strips are well-established, regular mowing of half of each strip at two-week intervals beginning with the onset of flowering usually works quite well. Some farmers may be tempted to harvest and remove the cuttings for livestock forage. This is acceptable for well-established, mature strips. However, a more highly recommended practice is to leave the cuttings on the strips to improve the habitat for beneficial insects.

Irrigation Methods and Practices

The Naturfarm enjoys a Mediterranean climate with a winter rainy season which is generally frost-free, and a summer that is cool and dry. During the winter, irrigation of the pest break strips usually is not necessary if rains are normal. In dry periods during the winter, an irrigation rate of one or two inches per month is sufficient. Once the rainy season is over, regular irrigation of pest break strips becomes necessary.

The goal is to maintain the plants in the pest break strip in a vegetative green and attractive condition. This is different from irrigating alfalfa for maximum production of forage. At the Naturfam, one to two inches every two weeks is sufficient for irrigating the pest break strips. Annual water requirements are about 3 acre-feet per year per acre of pest break strips. If the strips are also being managed for forage production, irrigation requirements may more than double.

Since irrigation is basic to the health and welfare of the pest break strips, all other activities need to be coordinated with the irrigation schedule. Mowing the pest break strips can alternate with the irrigation schedule, so that mowing occurs about a week after irrigation.

Role of the Commercial Insectary

Today, many species of beneficial insects and mites and other organisms are reared in commercial insectaries and sold for pest control. In the first year of operation, while pest break strips were being established at the Naturfarm, release of beneficial insects provided by a commercial insectary was the mainstay of our biological pest control program. These releases were energy- and cost-effective, although they did not always save the cash crop. As the pest break strips developed, some releases of beneficial insects were made directly into the strips, in addition to the target cash crops. This practice became increasingly effective as the alfalfa began to dominate in the pest break strips. Later sampling often showed the presence of not only the released beneficial species, but also related wild species that could not be insectary-reared. A neighboring field with a four-year-old stand of unsprayed alfalfa was the probable local source of the wild beneficial complex that quickly developed in the new pest break strips at the Naturfarm. A rapid buildup of aphid predators and parasites was especially noted. By the summer of 1990, it was difficult to find any aphids in the insect samples at the Naturfarm. When the first crops were planted in the fall of 1989, aphids were a major pest.

Engaging the services of a qualified Pest Control Advisor (PCA) was absolutely vital to the Naturfarm's successful transition to a certified organic vegetable farm, and is highly recommended to others who may wish to pursue this same course. The PCA can help to establish a mutually beneficial relationship between the on-farm insectary (i.e., in the form of pest break strips) and the off-farm commercial insectary as the farmer attempts to establish biological control methods and IPM strategies. The commercial insectary can also be a source of new species for biocontrol of newly-introduced or emerging pests.

Replacement and Renovation

Pest break strips, using alfalfa as the dominant plant, should last four to ten years or more before replacement or renovation is needed. Loss of stand due to gophers, insects, or disease may force an early replacement or renovation of a pest break strip. Usually, alfalfa does not follow itself in rotations due to an inhibitory effect preventing germination of alfalfa seed. This may force the fanner to move the pest break strips to new locations. At the Naturfarm, the pest break strips were renovated in their original locations rather than moving them. Between plantings, the seed mix was varied, starting with an alfalfa-based blend, followed by a cereal-based blend, followed by an alfalfa/clover mix in a rotation with about 12 to 18 months between plantings.

At the Naturfarm, pest break strips also function as internal borders for production fields. It would be inconvenient to adjust the official farm maps and field locations to accommodate moving or shifting the pest break strips. Each field contains a set number of beds that are numbered and measured. This allows very accurate tracking and planning for each bed in each field. Pest break strip beds are also the locator beds for marking the fields. However, on other farms, there may be reason to rotate areas devoted to pest break strips. Alfalfa is a soil improvement crop, and many field crops benefit from fol-10wing it in rotation. Farms already using alfalfa in rotation with other crops may derive some of the benefits of pest break strips by simply strip-cutting the alfalfa.

Management of Pest Break Strips to Enhance IPM

Pest break strips can form a vital link between the harmony and balance of nature and the need to prevent economic losses in crop production due to the activities of insect pests. IPM recognizes the inherent balance of nature and the role of natural controls in preventing damage from insect pests. One fundamental idea in integrated pest management (IPM) is to use natural controls whenever possible, and to use non-selective chemical sprays only if necessary to avoid serious economic damage to the crop.

Pest break strips can provide a stabilizing factor in today's farming systems and enhance the effectiveness of IPM. By providing crop diversity and suitable habitats, and by serving as on-farm insectaries, pest break strips can help to control secondary pests, and most primary pests, through natural biological control. By combining pest break strip management techniques with standard IPM practices, the farmer gains an added measure of pest control without resorting to chemical sprays.

Results of the CEC/Naturfarm Conversion Project

The CEC/Naturfarm Conversion Project was conceived as a study of the transition process that would develop strategies for helping farmers in converting from conventional agricultural practices, using chemical fertilizers and pesticides, to organic or nature farming systems. The study focused on energy and cost savings in three components of farm management: fertility, tillage and pest control. After five years, the results showed a clear energy and cost savings in the insect pest management component.

Biological Control of Insect Pests in Vegetable Crops

At the Naturfarm, 75 acres of diverse vegetable crops are managed without using non-selective sprays of any kind, whether organic, such as soaps and botanicals, or synthetic chemicals. The results are often acceptable to excellent. Many kinds of vegetable crops are produced without significant pest problems and attain the highest quality grading standards. Some crops are pest-free in certain seasons of the year, but come under in-creased pressure in the summer from *Diabrotica* and flea beetles. Crops in the mustard family are especially vulnerable to these two pests. The crop plan usually reduces the acreage in these susceptible crops during the period of vulnerability. This plan capitalizes on the strengths and avoids the weaknesses in certain crops at those times when pest pressures are high. The farm manager uses cultural controls, including crop variety selection, timing of operations, and crop planning, to gain the best advantage.

Table 4: Crops and Pests Most Conducive to Integrated Pest Management Using Pest Break Strips (Dietrick, 1989-1994; Lorenz and Maynard, 1988).

Crops	Pest Species Controlled	Pest Break Strip Effectiveness	IPM Management Notes
Lettuce	Aphid Flea beetle Leafhopper Leaf miner Looper	Good to excellent. Insect predators and parasites keep aphids and caterpillars under control;	Good control of aphids is strips kept in good condition; Occasional release of Lady beetle and Lacewing.
Tomato Pepper Potato	Aphid Flea beetle Leaf miner Cutworm Corn earworm Hornworm Whitefly Mite	Leafhopper and Leaf miner prefer alfalfa in pest break strips to other hosts.	Aphids can erupt if ant interference is uncontrolled, other pest under good control as for lettuce
Summer Squash Zucchini Yellow scallop Winter Squash Kabocha Butternut Acorn Spaghetti	Aphid Cucumber beetle (Diabrotica sp.) Leafhopper Leaf miner Mite Squash bug		Miner feeding damage of Diabrotica sp. Does not affect yields. Other pests under good control. No damage.
Carrot	Maggot		

Table 4 lists those crops and pests that are responsive to integrated pest management (IPM) using pest break strips as the primary pest management technique. These crops are produced regularly at the Naturfarm without significant problems from insect pests. In 1994, for example, 8,500 boxes of lettuce were produced and sold for $97,000 without sprays of any kind applied to the crops. Lettuce, carrot, summer and winter squash, pumpkin, tomato, pepper and potato were all produced without significant pest problems.

Crops and pests with moderate to good response to integrated pest management using pest break strips are listed in Table 5. These crops may require additional pest management beyond simply maintaining the pest break strips. Releases of insect predators and parasites may be helpful at critical stages of crop growth or at various seasonal transition points. For example, aphid populations can literally “explode” in the early spring, and the local population of predators and parasites may need to be increased by releases from commercial insectaries. Caterpillar pests are usually controlled effectively with pest break strips. However migrations from the surrounding foothills and other natural areas may increase pest pressure.

A key transition time in much of California begins when the dry season starts in the late spring/early summer. This is when many pests migrate to crop fields in search of food and water. Therefore, it is important to have the pest break strips in lush condition at this critical period so that pests will be attracted to the strips instead of to the cash crops. Bt, predatory nematodes and other IPM measures may be needed to supplement pest break strips and releases of beneficial insects for the crops and pests listed in Table 5.

Table 5: Crop and Pests with Moderate to Good Response to Integrated Pest Management Using Pest Break Strips (Dietrick, 1989-1994; Lorenz and Maynard 1988).

Crops	Pest Species Controlled	Pest Break Strip Effectiveness	IPM Management Notes
Cucumber	Spotted cucumber beetle (*Diabrotica sp.*)	Moderate to good.	Aphids may need releases of Lady beetle and Lacewing.
Greens Swiss chard Red chard Spinach	Diabrotica sp. Flea beetle	Additional management needed, such as timed plantings to escape pest pressure, especially to avoid mid-summer flea beetle infestations.	Caterpillars under good control usually; may need a spray of Bt if out of control.
Cole Crops Broccoli Cabbage Kale Kohlrabi	Aphid Flea beetle Looper Cabbage worm Diamondback moth	*Diabrotica sp.* and flea beetle cause most of the problems and damage; may be controlled by botanical pesticides.	Predatory nematodes may be sprayed to control *Diabrotica* and flea beetle larvae in soil.
Green Bean	Aphid Diabrotica sp. Mite		
Red beet	Aphid Flea beetle Leaf miner		
Snowpea	Aphid		

In southern and central California, year-round vegetable production is possible. The fall-winter-spring shipping markets are major windows of opportunity for California vegetable producers. The coastal zone is a primary producer of summer, cool-season vegetables, such as lettuce, broccoli and carrots. The Naturfarm is located in the southern California coastal zone near

Lompoc and Santa Maria. Broccoli, cabbage, spinach, chard and beets grow well with few insect problems during the fall and spring production/marketing window. As the warm, dry summer approaches, there are more problems with insect pests for these crops. Tables 5 and 6 list the problem crops and insects for the difficult mid-summer/dry season production period. Supplemental IPM techniques are often required for these crops and pests at this time. Attention to details of individual crop production and pest-control requirements can still produce maximum economic crop yields. Phenology modeling of pests may help refine IPM techniques such as releases of beneficial insects, sprays of Bt and other controls.

Table 6: Crops and pests with Limited Response to Integrated Pest Management Using Pest Break Strips. Additional IPM Measures are Required (Dietrick, 1989-1994; Lorenz and Maynard,1988).

Crops	Problem Pest Species	Pest Break Strip Effectiveness	IPM Management Notes
Summer Cole Crops and Crucifers Broccoli Cabbage Collared Kale Kohlrabi Mustard Turnips Daikon Radish	Flea beetle *Diabrotica sp.*	Massive migrations from off-farm sites during summer dry season limits effectiveness of pest break strips. Supplemental IPM measures needed to maintain pest damage at subeconomic levels.	Predatory nematodes may help control larval stage of flea beetle and *Diabrotica sp.* Sprays of botanical pesticides may help control adult flea beetle and *Diabrotica sp.*
Red Beet	Flea beetle *Diabrotica sp.*		
Greens Spinach Swiss chard	Flea beetle *Diabrotica sp.*	Few predators and parasites available to control adult reproductive stage of these pests.	*Trichogramma sp.* releases and Bt sprays may help to control earworm and borer.
Sweet Corn	Corn earworm Corn borer *Diabrotica sp.* Flea beetle		

Energy Use and Cost Analysis

The CEC Naturfarm Conversion Project provided a unique opportunity to study the transition process during an abrupt conversion from a conventional, chemical-based agriculture to an organic or nature farming system. A projection of energy and cost savings for the organic or nature farming system compared with conventional agricultural practices was based on the experiences of an earlier study known as the Camarillo Naturfarm Project (NFRDF, 1988). Two models were developed, one for nature farming and one for conventional agriculture, which compared these two systems with respect to energy and costs for tillage, soil fertility and pest control. The data for the Nature Farming Model was based on data from the Camarillo Naturfarm. The data for the Conventional Fanning Model was based on published information from the University of California Cooperative Extension Service (Brendler, 1983; 1990); the University of Arizona Cooperative Extension Service (Olson and Horel, 1981); and the Handbook of Energy Utilization in Agriculture (Pimentel, 1980).

In comparing the energy use and cost savings for the conventional farming model and the Naturfann model, all data for labor hours, equipment hours and input supplies were converted into gallons of “diesel fuel equivalents.” Three principal farm operations were compared, i.e., tillage, soil fertility and pest control. The basis of this comparison was a 60-acre model organic farm of the Naturfarm type. The comparative costs of these farm operations for conventional vs. organic farming are reported in Table 7. In all cases, the costs were higher for conventional farming compared with organic farming. This is not too suprising since conventional farming follows a more intensive tillage program than organic farming, reflecting the higher energy costs. Moreover, conventional farming utilizes more costly chemical fertilizers to maintain soil fertility and pesticides to control insects and diseases. By contrast, organic farming utilizes green manure crops and compost to supply plant nutrients and integrated (non-chemical) pest management strategies (i.e., pest break strips) to control pests. The results indicate a substantial annual cost savings for the entire 60-acre farm when managed according to the organic farm model compared with the conventional model.

Table 7: Cost Savings for Farm Operations per Acre and per Year for a 60-Acre Model Organic Farm of the Naturfarm Type Compared with a Conventional Farming Model.

Model	Cost of Farm Operations ($US/acre)			
	Tillage	Soil Fertility	Pest Control	Total
Conventional	53.15	193.30	408.11	654.56
Organic (Naturfarm)	40.72	156.10	317.37	514.19
Cost Savings for the organic farm model:				
per crop acre	12.43	37.20	90.74	140.37
2 crops/acre/year	-----	-----	-----	280.74
2 crops/60 acres/year	-----	-----	-----	16,844.40

Energy Conservation and Efficiency in Crop Production

The foregoing results on energy requirements and cost analysis were used for comparing energy use efficiency in crop production for the Naturfarm model and an updated Conventional Farming Model. Four crops grown at the Naturfarm during 1991-1992 were used for this comparison including carrot, leaf lettuce, summer squash and sweet corn (Dietrick et al., 1995).

As shown in Table 8, the cost of weed control was higher for all four crops grown organically mainly because of the higher labor and energy costs for hand weeding and mechanical cultivation. However, the cost of controlling insect pests was lower in all cases compared with conventional farming largely due to the pest break strips. For carrot, the tillage and fertility costs were only slightly lower than for conventional methods. The lower yield may reflect a lower planting density; however the organic premium price received for this crop ensured a gross income per acre that was comparable to conventional farming.

Table 8: Production Costs, Yields and Gross Income for Four Organically-Grown Crops at the Naturfarm Compared with Conventional Farming Methods.

Crop	Production Costs					Yield	Gross Income
	Tillage	Fertility	Weeds	Insects	Total	(wt/ac.)	($/ac.)
Carrot	lower	lower	higher	lower	higher	lower	lower
Leaf Lettuce	similar	higher	higher	lower	similar	lower	similar
Summer Squash	higher	higher	higher	lower	higher	lower	similar
Sweet Corn	higher	higher	higher	lower	higher	higher	similar

Total production costs for leaf lettuce were approximately the same for both organic and conventional methods. Again, while yields were lower for organically-grown lettuce, the premium price received resulted in a gross income per acre that was comparable to lettuce grown conventionally. In the case of summer squash grown organically, the total production costs were higher and yields were lower than for conventional methods; however, gross income was the same because of the organic premium price received in the marketplace. Sweet corn presented a unique situation. While the total production costs were higher for organically-grown sweet corn, yields were also higher than for conventional methods. Since the higher costs were offset by higher yields, the gross income from organic production was essentially the same as conventional.

The total energy required in the production of carrot, leaf lettuce, summer squash and sweet corn for the conventional model was equivalent to 150, 15, 60 and 79 gallons of diesel fuel per acre, respectively. In the Naturfarrn model, these same crops were produced with the equivalent of only 19, 36, 25 and 29 gallons of diesel fuel per acre, respectively. Thus, the production of carrot, leaf lettuce, summer squash and sweet corn by the Naturfarm method resulted in a savings of 87, 66, 58 and 63 percent, respectively, when compared with the energy expended in producing these crops in a chemical-based fanning system. Such a dramatic conservation of energy can be attributed mainly to:

- Savings in nitrogen fertilizer costs from biological nitrogen fixation by the green manure/legume cover crops.
- Energy savings from biological control of insects in the pest break strips.
- Reduction in energy using a controlled-traffic, “permanent bed,” minimum-tillage system.
- Energy savings from eliminating herbicides for weed control.

Summary and Conclusions

Pest break strips represent a new perspective for integrated pest management and a potentially valuable strategy for farmers who wish to enhance biological stability in their pest management programs, and to take advantage of the highly effective biological controls that exist in nature. Experience, research and study at the Naturfarm in Lompoc, California show that pest break strips are energy-efficient, cost-effective, and field-proven alternatives to chemical fertilizers and pesticides for many vegetables crops. Pest break strips can be a useful tool, not only for organic producers, but for conventional farmers seeking to reduce their use and dependence on chemical pesticides while adapting other IPM methods in their farming operations. Additional research will be needed to refine certain aspects of the pest break strip technology to ensure its successful application to a wide range of agroecological conditions and farming systems. Nevertheless, we are confident that the technology as it exists today provides an exciting new dimensions for IPM that can contribute to a more sustainable agriculture and environment.

References

Brendler, R. A. 1983. Costs and Practices in Ventura County for Lima Beans and Vegetables. Ventura County Cooperative Extension Service, Ventura, California, USA.

Dietrick, E. J. 1989-1994. Reports on Insect Surveys at the Naturfarm. Personal Communications. CEC Naturfarm Conversion Project. Nature Farming Research and Development Foundation, Lompoc, California, USA.

Dietrick, E. J., J. M. Phillips and J. Grossman. 1995. Biological Control of Insect Pests Using Pest Break Strips: A New Dimension to Integrated Pest Management. Final Report of the CEC Naturfarm Conversion Project. Submitted to the California Energy Commission, Farm Energy Assistance Program. Nature Farming Research and Development Foundation, Lompoc, California, USA. 39 p.

Drlik, T. 1995. Everett Dietrick-Biological control pioneer. IPM Practitioner 17(1):1-8.

Lorenz, O. A. and D. N. Maynard. 1988. Knott''s Handbook for Vegetable Growers. p. 272-287. Third Edition, John Wiley & Sons, New York, N.Y., USA.

NFRDF. 1988. The Naturfarm Conversion Project. Proposal Submitted to the California Energy Commission, Farm Energy Assistance Program. Nature Farming Research and Development Foundation, Lompoc, California, USA.

Olson and Horel. 1981. Arizona Farm Machinery Costs. Arizona Cooperative Extension Service, Department of Agricultural Economics, Tucson, Arizona, USA.

Pimentel, D. 1980. (ed.). Handbook of Energy Utilization in Agriculture. CRC Press, Inc., Boca Raton, Florida, USA.

Schlinger, E. 1. and E. J. Dietrick. 1960. Biological control of insect pests aided by strip-farming alfalfa in experimental program. California Agriculture 14(1) : 8-9, 15.

Stem, V. M., R.van den Bosch and T. F. Leigh. 1964. Strip cutting alfalfa for lygus bug control. California Agriculture 18(4):4-6.

Stern, V. M. et al. 1967. Lygus Control by Strip Cutting Alfalfa. AXT-241. University of California Agricultural Extension Service, Riverside, California, USA. 13 p.

University of California Cooperative Extension Service. 1990. Projected Production Costs for Vegetable Crop Production in Imperial County, California. Sweet Corn, Broccoli and Lettuce. Imperial County Cooperative Extension Service, E1 Centro, California, USA.