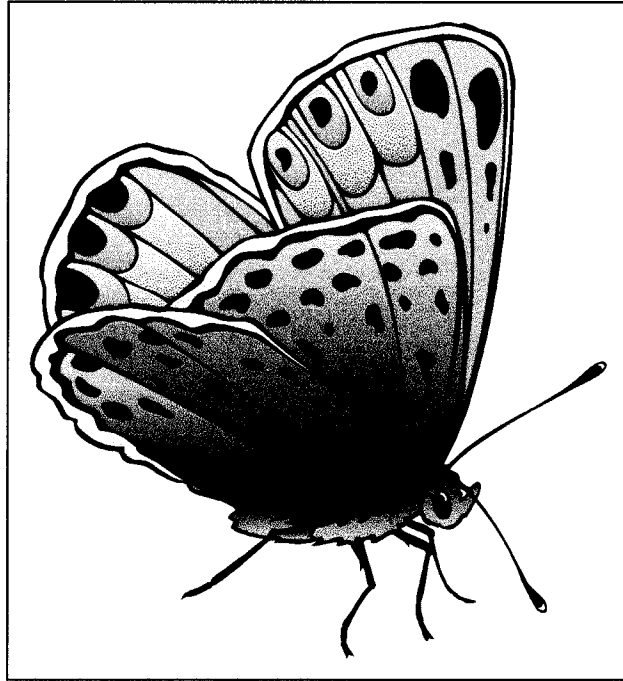


**Biological Control of Insect Pests
Using Pest Break Strips
A New Dimension to
Integrated Pest Management**



**Everett J. Dietrick
John M. Phillips
Joel Grossman**

**A Publication Of
The Naturfarm Conversion Project**

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Foreword

The 1980 U.S. Department of Agriculture Report and Recommendations on Organic Farming indicated that there was a growing concern among farmers, consumers, environmentalists and society as a whole on the adverse effects of pesticides on human and animal health; environmental quality and biodiversity; and food safety and quality. Consequently, the Report urgently recommended that the U.S. agricultural research establishment seek to develop "new and improved techniques for control of weeds, insects and plant diseases using biological, non-chemical methods." The Report placed particular emphasis on "the development of pest control methods using parasites, predator insects, and other biological means to eradicate or control unwanted (i.e., harmful) species."

While this recommendation resulted in some renewed interest in biocontrol methods and Integrated Pest Management (IPM), there was little additional support for such research in the years which followed. That is, research continued to focus on ways of increasing the production of basic commodity crops in chemical-based, monoculture, conventional farming systems.

Nevertheless, by the late 1980's, consumer and environmental groups had become very prominent and vocal in expressing their concerns about the use of synthetic chemicals, i.e., fertilizers and pesticides, in our food production system. Subsequently, the impact of this movement led to two significant events with regard to U.S. agriculture. First, in June 1993, the National Academy of Sciences, National Research Council published a report entitled Pesticides in the Diets of Infants and Children which indicated that this particular age group could be at higher risk than adults from ingestion of fruits and vegetables containing pesticide residues. And second, also in June 1993, a joint statement was issued by the Secretary of Agriculture (USDA); the Administrator of the U.S. Environmental Protection Agency (USEPA); and the Commissioner of the U.S. Food and Drug Administration (USFDA) that officially committed these agencies to work together with U.S. farmers to reduce their use of, and dependence on, pesticides, and to promote the principles of sustainable agriculture.

The 1980 USDA Report also revealed that farmers who had converted abruptly from conventional, chemical-based agriculture to organic or nature farming systems without synthetic pesticides often experienced serious weed, insect and disease problems during the first three to four years after conversion had begun. Thus, in view of this and the two events cited in 1993, perhaps the most frequently asked question by U.S. farmers is "How can I accomplish such a conversion from conventional to organic or nature farming successfully and profitably, and with minimum risk?"

These historical and recent events are relevant because they underscore the goals and objectives of the California Energy Commission/Naturfarm Conversion Project, a five-year study which began in 1989. This report on the Biological Control of Insect Pests Using Pest Break Strips represents only one aspect of the overall project. The results of systems research and analysis of other components, including tillage, soil fertility, pest management and farm management, will be presented in other reports available from the Nature Farming Research and Development Foundation. Meanwhile, this report on pest break strip technology appears to offer a new and exciting approach to biological control, and an added dimension to Integrated Pest Management (IPM). The concept of pest break strips and their practical application should provide a more effective and reliable approach to the conversion from conventional agriculture to a nature/organic farming system. Moreover, when farmers realize that the Nature Farming Model can result in a substantial reduction in the energy needed for such production inputs as tillage, soil fertility, weed control, and insect pest management, their interest level will increase accordingly.

Certainly, additional research will help to refine the methods and techniques described in this report to a) enhance its adaptation over a wide range of agroecological and climatic conditions; and b) promote its acceptance and use by commercial farmers, both organic and conventional. Nevertheless, the results presented herein are scientifically-credible, convincing, and worthy of further on-farm testing and demonstration. The California Energy Commission/ Naturfarm Conversion Project is an excellent example and model of how resources can be integrated into more sustainable farming systems that are energy-efficient, environmentally-sound, and economically-viable. This report is both timely and innovative, and should be widely read by farmers, researchers and extension workers.

Dr. James F. Parr
President, Nature Farming Research
and Development Foundation
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and
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Preface: The Naturfarm Conversion Project

In 1989, the California Energy Commission (CEC) funded the Naturfarm Conversion Project to demonstrate the conversion process from an energy intensive farming system to a production system with less dependence on chemical and fuel energy use. The purpose of the CEC's Agricultural Energy Assistance Program (AEAP) is to promote the efficient use of energy resources in California's food and fiber industry. To achieve its purpose, the AEAP provides funding for applied research and demonstration projects to monitor and evaluate targeted technologies and farming practices that could help farmers reduce energy consumption.

The goal of the Energy Commission in funding the Naturfarm Conversion Project was to demonstrate energy conservation practices to reduce pesticide and fertilizer use, and achieve fuel use savings. Additional goals were set to achieve agricultural resource use efficiencies, reduce soil, air and water contamination, and limit worker exposure to harmful chemicals. The project was designed to document project results, assess benefits to the farmer, and develop educational materials.

The purpose of this technical report is to document the transition experience of converting a conventionally-farmed land area to a biologically-integrated farming system. In addition, it is hoped that the benefits of using the Naturfarm practices will become apparent and some of the successful methods described in this transition guide will be adopted by farmers. The results of this project should help to develop a greater appreciation of energy costs and how farming systems can become more energy efficient.

The Naturfarm has achieved a high level of energy efficiency by eliminating the use of chemical fertilizers and pesticides, and reducing diesel fuel consumption by eliminating pesticide applications and using conservation tillage practices. These results have been evaluated and summarized after four years of field research and test demonstrations. The project results reflect an overall improvement in the farm's effectiveness to control pest damage. Improvements also have been documented in crop quality and gross revenue, reduced pest problems, and better monitoring and management skills. Farm personnel have become more knowledgeable about insect ecology and biological control practices. Additional benefits have been measured in decreased fuel consumption, reduced soil compaction, and increased water infiltration and retention. Improved management skills have contributed to the development of a whole farm systems approach to decisions on production practices. We hope that reading this document will assist farmers as they strive to develop more energy efficient farming systems.

Ricardo Amon, Agricultural Energy Assistance Program
California Energy Commission

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The contributions and dedication of those who served at various times as members of the CEC Naturfarm Conversion Project Team are acknowledged with sincere thanks and appreciation. Project Team Members were Ricardo Amon, Warren Bendixon, Everett Dietrick, Paul Dilger, Bill Gillette, Ron Gilman, Stephen Gliessman, Bill Liebhardt, Harlyn Meyer, James Meyer, Philip Northcraft, John C. Phillips, John M. Phillips, Thomas Ruehr, Louie Valenzuela, and Victor Wegrzyn.

Dr. Teruo Higa provided technical counsel throughout this project on Kyusei Nature Farming and the use of EM technology, and his assistance is sincerely appreciated with many thanks.

Harlyn and James Meyer designed and initiated the CEC Naturfarm Conversion Project and served as initial NFRDF Project Manager and Cooperating Farmer, respectively. Their contributions and service over many years, both to Nature Farming and to the organic farming movement in California, are recognized and appreciated.

Izuo Miyashita, President of NFRDF(1990-1994) gave wholehearted support to the CEC Naturfarm Conversion Project, which contributed immeasurably to its success. Dr. James F. Parr, President of NFRDF since 1995, has continued this support for the Project, and has served as Executive Editor of this Report. Dr. Sharon B. Hornick, Executive Director of NFRDF, contributed valuable comments and insights to this Report, and has fully supported this Project. Ann Mayse (UC-SAREP) reviewed and assisted in editing the Report and Susan E. Randall (NFRDF) also provided valuable comments and editorial assistance.

Lastly, Ricardo Amon, Project Manager for the California Energy Commission and John M. Phillips, Project Manager for NFRDF and the Naturfarm, have been instrumental in leading the CEC Naturfarm Conversion Project to a successful conclusion, which includes this Report. Sincere thanks and appreciation are extended to all who have contributed to the success of this Project.

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Biological Control of Insect Pests Using Pest Break Strips

A New Dimension to Integrated Pest Management

I. Introduction

Pest break strips are an essential part of the Naturfarm's transition strategy for enhancing the biological control of insect pests. They are a specialized form of strip-intercropping and provide a new dimension to integrated pest management (IPM). At the Naturfarm, pest break strips of an alfalfa-clover mixture are strip-intercropped with organic vegetables. Pest break strips have a dual role: 1) as trap crops, they divert pests away from market crops; and 2) as insectary crops, they grow beneficial insects helping to provide biological control of pests in adjacent rows of vegetable crops (Grossman and Quarles, 1993).

At the Naturfarm, a cultural practice known as strip-cutting maximizes the number of pests and the populations of natural enemies found in pest break strips. Strip-cutting is simply the practice of cutting only half the pest break strip at any one time. This allows half the pest break strip to flower prior to cutting, while the other half is in mainly a 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).

The exclusive reliance on natural biological control organisms and cultural practices like strip-cutting for sustainable insect pest management is rarely, if ever, attempted anymore. Such methods are almost unprecedented for vegetable crops. However, there have been times and places in California's agricultural history where such methods have provided all of the pest control needed for the production of major commercial crops such as citrus, cotton and alfalfa.

II. Historical Background

Everett J. "Deke" Dietrick, a registered entomologist and widely recognized authority on biological control of insect pests, served as the Naturfarm's Pest Control Advisor (PCA) on the CEC Naturfarm Conversion Project. Dietrick worked in southern California on cotton, citrus and alfalfa during a time when natural biological control techniques were the predominant methods used to control insect pests. Over the last 50 years, while a researcher at the University of California, Riverside, and later in private practice with Rincon-Vitova Insectaries, Inc., Dietrick helped develop, monitor and implement IPM techniques, such as strip-cutting and classical biological control releases, in unsprayed California cotton, citrus and alfalfa (Drlik, 1995). Dietrick drew upon his personal knowledge, based on decades of experience on biological control successes in southern California, to develop the IPM program for the Naturfarm.

A system similar to that designed for the Naturfarm's pest break strips and used for the production of vegetable crops was described by Marcovitch (1935). In those early experiments, strips of turnips, a good cabbage aphid host, were planted a month ahead of market cole crops as insectary plants to attract aphid natural enemies. The turnips were partially destroyed by aphid infestations by late spring or early summer. However, predators like lady beetles and parasitic wasps like Lysiphlebus testaceipes (Cresson) provided biological control of aphids for most of the season in the nearby market crops.

Naturfarm's pest break strips were designed to make this type of biological control a more permanent feature of vegetable farms. Part of making this system more permanent and effective is the use of strip-cut alfalfa which was first adapted for biological pest control in 1956 by Evert I. Schlinger and Everett J. Dietrick as part of the University of California's statewide effort to control the spotted alfalfa aphid.

Strip-cutting of alfalfa was devised in the 1950's as a means of maintaining beneficial insects in the field as a "defensive army" preventing population explosions of aphids and other pests from occurring in new crop growth (Dietrick, 1989-94). Strip-harvesting half of the field following each irrigation (12-to 14-day intervals), compared with complete harvesting of the field after the usual two irrigations (25 to 30 days), traps and protects the vast numbers of beneficial arthropods that were previously lost. When adapted to use in pest break strips, a 12-to 14-day cutting interval is also important because pests like adult Lygus bugs begin moving out of maturing hay when alfalfa reaches three-fourths maturity.

During the 1960's, University of California researchers Stern, van den Bosch and Leigh (1964) documented this added value of uncut alfalfa as a trap crop for Lygus, which can severely damage strawberries, cotton and vegetable seed crops. Continuously cutting the pest break strip before seed set prevents alfalfa and other pest break strip crops from becoming too favorable for seed feeders such as Lygus bugs and certain leafhoppers. If the entire pest break strip is cut and there is no nearby uncut alfalfa then Lygus and other pests typically migrate into nearby market crops. Besides "trapping" pests like Lygus, strip-cutting also retains beneficial insects, mites and spiders, which increase in number by feeding on small soft-bodied insects thriving in the young, tender strip-cut regrowth.

In their historic report on numbers of beneficial insects in strip-cut alfalfa in southern California, Schlinger and Dietrick (1960) counted 400 percent more natural enemies per acre in strip-cut alfalfa, compared with cutting and harvesting the whole stand. Alfalfa plants also yield 15 percent more biomass when managed by strip-cutting, which gives an extra ton of hay per acre per season. When the cut alfalfa is sheet-composted rather than removed from the field, an expanded food chain of decomposing organisms feeds an even more diverse and abundant fauna of beneficial

arthropods. An estimated one thousand species of insects, mites and spiders interact in a strip-cut alfalfa field that is not sprayed with pesticides. The increased numbers of insect predators and parasites in strip-cut alfalfa reported by Schlinger and Dietrick in 1960 and shown in Table 1 convinced Naturfarm management that this approach was worth adapting for pest break strips in diversified vegetable farming.

Table 1. Comparison of Numbers of Beneficial Arthropods in Strip-Cut and Full-Cut Alfalfa.¹

Beneficial Arthropod	Strip-Cut (No./Acre)	Full-Cut (No./Acre)	Increase From Strip-Cut (%)
Predatory Spiders	1,000,000	100,000	1000
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	2000

¹ Based on the Data of Schlinger and Dietrick, 1960.

If one were to purchase the numbers of beneficial arthropods that can be grown through the management of strip-cut alfalfa, it would be prohibitively expensive (Schlinger and Dietrick, 1960). At the Naturfarm, pest break strips of strip-cut alfalfa became on-farm insectaries, producing numerous beneficial arthropods close to cash crops which created a highly-effective biological control system for the management of insect pests in vegetable crops.

Historically, economics helped make unsprayed strip-cut alfalfa a regional reservoir of natural biological control agents for insect pests in southern California. The reason for this was that it was not cost-effective to spray alfalfa, and existing equipment could only harvest a limited area at one time. This changed when it became economically viable to spray alfalfa with pesticides and when the use of larger equipment and custom harvesting became the norm. When alfalfa and other crops producing beneficial biological controls are sprayed, there may be dramatic and costly consequences affecting an entire region. For example, in recent years in California's Imperial Valley, massive migrations of secondary pests like whitefly has affected the production of cotton and winter vegetables. Imperial Valley vegetables, like lettuce, broccoli, cantaloupe and cabbage, now suffer from devastating whitefly invasions that have replaced the migrations of insect predators and parasites from alfalfa fields.

Insect pest management at the Naturfarm uses pest break strips consisting of alfalfa and clovers to enhance plant and insect biodiversity. The staggered cutting schedule also enhances biodiversity by providing plants of different ages or maturities. The net result of this increased biodiversity is an IPM program of great ecological stability because it provides beneficial insects with permanent refuge to help prevent devastating pest population outbreaks.

III. Function, Design and Operation of Pest Break Strips

A Habitat for Insect Wildlife

The pest break strips at the Naturfarm are more than just a shift away from spraying pesticides of one form or another, they are really about creating a habitat for beneficial insect wildlife. Just as maintaining wetland habitats for migratory waterfowl is essential for a healthy ecology, it is necessary to create permanent or semi-permanent, on-farm habitats for beneficial insect, mite and spider populations. Providing habitats for beneficial organisms is as essential to achieving sustainable biological control on vegetable farms as wetlands are to maintaining the existence of ducks and other aquatic wildlife in agricultural areas. In essence, pest break strips are wildlife refuges for natural enemies of agricultural pests. This role as the protector of beneficial wildlife is one of the longest-held traditions of farming. Pest break strips are a tool that helps the farmer to maintain this tradition while protecting his crops from insect pests.

Design and Layout

The Naturfarm is using pest break strips in an attempt to create the biological control benefits of unsprayed and strip-cut alfalfa. Five to ten percent of the land base of farmable acres is planted to 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. The layout of the strips on the farm is shown in Figure 1.

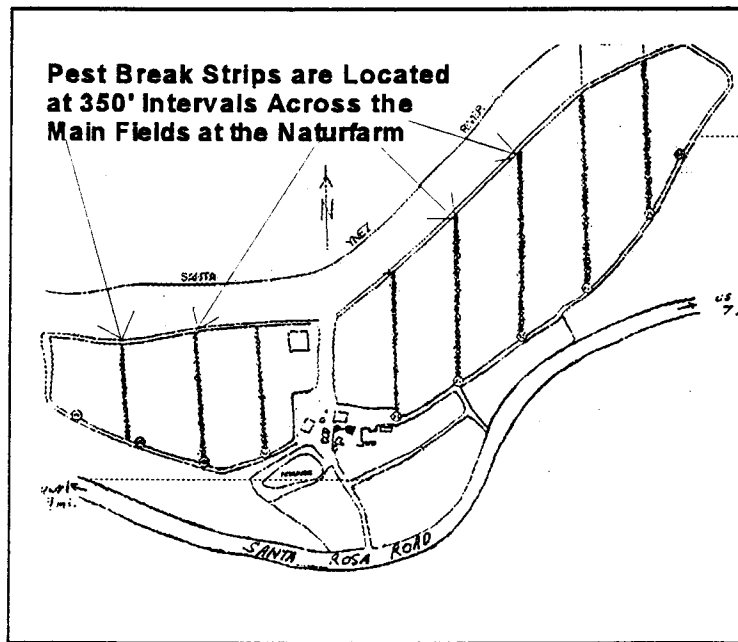


Figure 1. Layout of Pest Break Strips at the Naturfarm.

Five years of experience at the Naturfarm has provided valuable information about the design and operation of pest break strips. For example, it takes time for pest break strips to become fully effective. Alfalfa and other perennial species take time to become established due to their growth characteristics. It may take three to six months following planting for pest break strips to become established well-enough to begin strip-cutting. Initial strip-cutting for the first year may have to be staggered at greater intervals to allow plants to recover and continue their root and crown development. Thus, it is recommended that pest break strips be planted up to a year ahead of when they are needed to protect cash crops from damage.

When first setting up this system at the Naturfarm, pest break strips were newly planted right along with cash crops, and sometimes, well after cash crops were already started. As a result, insect damage on these first cash crops was often severe and typical of organic farming operations at startup. Releases of beneficial insects from a commercial insectary could not control insect damage to sub-economic levels. In the following six to nine months, there was a dramatic reduction of pest activity and crop damage. Predator and parasite species increased rapidly in pest break strips and throughout the farm. This development of effective biological control was documented by Dietrick at monthly intervals during this critical transition phase.

Some comments from Dietrick's reports after the first year are noteworthy:

- "The insect populations on the farm are at least 10 fold less this year than last, and the good bug / bad bug ratio has switched dramatically in favor of the beneficials. There are still flea beetles and cucumber beetles, but much fewer in number and they offer minimum threat to crop production at this time."
- "This biological control by natural enemies is dependable because there are so many backup systems of beneficials that help maintain this low level pest population. Take away this natural enemy complex and pest populations explode. This is what chemical addiction is all about. When the natural enemies are destroyed, there is no other recourse than to spray periodically, suppressing the pest populations with poisons until the crops are harvested."
- "Marketable crops of all kinds of vegetables are being grown without the use of any pesticides. The success of this farming system is undeniable, and it can be improved with time and management."

To be effective, pest break strips need to 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 out pest break strips perpendicular to the prevailing wind if possible. This orientation maximizes the pest trapping effects and facilitates distribution of beneficial arthropods to the pest crop. Intervals between strips should be between 350 and 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. As little as 5 percent of the production area may need be dedicated to pest break strips. At the Naturfarm, it was found that the economic value of the 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. Further information on this point is reported in Section V. Results.

Pest break strips provide another function at the Naturfarm by serving as reference point beds for our permanent bed tillage system. During tillage operations, bed row marks and wheel tracks are temporarily erased in the field. Beds are then remarked by going over the last bed in the adjacent pest break strip and making a clear line for marking the field. In this way, wheel tracks and bed row marks can be reestablished very close to the original settings.

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 because 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 80-inch centers is a recommended minimum area for an effective pest break strip that is easy and efficient to manage. Obviously, an important design consideration is the width of the equipment that will be used to manage the bed preparation, planting, strip-cutting, insect vacuuming and irrigation operations. At the Naturfarm, all equipment is designed to work with a permanent bed system that uses 80-inch centers as a uniform standard throughout the farm. Other farms may wish to use separate equipment to manage pest break strips like forage crops and manage vegetables as row crops.

As a forage crop, alfalfa is usually flood irrigated. Irrigation schedules aim to apply water at 12-to 14-day intervals. Alfalfa can use considerable water when grown for forage, as much as 10 acre-feet per season in warm climates. At the Naturfarm, pest break strips were planted on our standard 80-inch raised beds and sprinkler irrigated.

Sprinkler irrigation was convenient, as this was the standard practice for the farm. However, growing alfalfa on raised beds and using sprinkler irrigation can cause some problems that can be eliminated by using flood irrigation. Gophers are often a problem in raised bed, sprinkler-irrigated alfalfa. Flood irrigation helps control gophers by submerging their nests and burrows. Also, sprinkler pipe dedicated to irrigating pest break strips is in demand for use on cash crops. Sometimes, the need to irrigate cash crops conflicts with the need to irrigate the pest break strips. At the Naturfarm, pest break strips are so essential to insect pest management that sprinkler pipe, valves and main line are dedicated exclusively for this purpose. Also, pest break strips are deliberately located near the risers that connect the above ground mainline with the underground 12-inch main feeder line from the pumps. This makes it convenient to water the pest break strips. For farms not using a permanent bed system, setting up pest break strips for flood irrigation is a recommended practice whenever possible. Pest break strips should always be located near a source of irrigation water where irrigation is required for crop production.

Plant Selection and Blends

The first pest break strip, planted in 1990, was a mixture of alfalfa, strawberry clover and orchard grass. In 1992, the Naturfarm switched to a commercially available insectary blend designed to attract beneficial insects. In 1994, the Naturfarm changed to a blend of alfalfa and four clovers.

The choice of plant species used in the pest break strips is arbitrary, so long as alfalfa is included as a dominant component of the mixture. Alfalfa seems to attract the most insect pests and their predators and parasites, and is the most amenable plant species for strip-cutting. It is important to select mostly perennial species for use 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-lived and may not last year-round or for the whole growing season.

The Naturfarm learned by experience that insectary blends based on annual and biennial plant species are designed for other uses and are not suitable for pest break strips. Annual and biennial plants are most attractive to beneficial species as nectar and pollen sources when they are in flower. In pest break strips, annual and biennial species usually do not complete their life cycle or produce flowers due to the strip-cutting management technique. Insectary blends may be more useful as border strips and trap crops. As border strips, they can serve as refuges and nectar sources for insect predators and parasites. As trap crops, they can be timed to draw pests away from cash crops. Trap crops can also catch and hold pests where they can be controlled by other means, such as by insect vacuums or by sprays.

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 with the insectary plants serving as a trap crop for the flea beetles, thereby averting damage to the cash 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. See Table 2 for the plant species composition of the three blends tested at the Naturfarm from 1990 to 1995.

Table 2. Plant Species Composition of Three Blends Tested for Use in Pest Break Strips at the Naturfarm (1990-1995).¹

Blend	Species	Composition (%)
Original Naturfarm Blend No. 1 (1990-1992)	Alfalfa	70
	Pasture Grass	20
	Strawberry Clover	10
Beneficial Blend (Manufactured 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
Vegetables, Various	2.5	
Naturfarm Blend No. 2 (1994-1995)	Alfalfa	60
	Dutch White Clover	10
	Strawberry Clover	10
	Berseem Clover	10
	Crimson Clover	10

¹ All Blends Mixed at Lohse Mills, P.O. Box 168, Atrois, CA 95913.

It is useful to keep in mind that the pest break strips are similar to a livestock rearing operation because their function is to grow beneficial insect predators and parasites. Insects, like most livestock, benefit from a diet of high protein plants like alfalfa. In fact, insects grow in greater number and diversity on alfalfa than on most any other domesticated plant (University of California Statewide IPM Project, 1981). The results of two samples taken one week apart in March 1994 record the comparative abundance of insect life in a cover crop of Naturfarm Blend No. 2 (Alfalfa/Clover Mix) and in two pest break strips planted to the Beneficial Blend Mix (Annuals/Biennials Mix) as shown in Table 3.

Table 3. Comparison of Insect Counts in Beneficial Blend and Naturfarm Blend No. 2.¹ (Average of two samples, one week apart, in March 1994. Each sample consists of 50 sweeps with a standard insect sweep net.)

Species or Group	Beneficial Blend Pest Break Strip 4	Beneficial Blend Pest Break Strip 5	Naturfarm Blend No. 2 Field 9/10
Ants	0	1	2
Aphid	9	4	144
Cucumber Beetle	2	2	5
Flies (1/2 Benef.)	12	8	43
Wasps	6	6	0
Lady Beetle	1	0	56
Leafhopper	2	2	3
Caterpillars	2	1	9
Lygus	1	0	5
Spiders	3	3	8
Weevil, Alfalfa	1	0	20
Total:	39	27	295
Pests:	23	14	209
Beneficial:	13	13	86
Ratio: (P/B):	1.8	1.1	2.4

¹ P. D. Northcraft, 1994, Personal Communication.

The data shown in Table 3 demonstrate the ability of the alfalfa/clover mixture to produce abundant crops of beneficial predators and parasites. Pests are also produced in greater numbers on the alfalfa-based mix. This is one of the paradoxes of using the pest break strip system. A primary function of the pest break strips is to produce pests in sufficient abundance to attract and feed large numbers of beneficial predators and

parasites. In this sense, larger numbers of pests in the pest break strips are desirable. Because pests as well as beneficial species are produced in the pest break strips, proper management and care are very important. Neglect of the strips can result in their becoming a liability by producing pests rather than an asset that produces beneficial natural biological control organisms.

Economic Value and Benefit

The economic value and benefit of pest break strips need to be recognized. Table 4 provides some indication of the dollar value of some of the beneficial arthropods produced per acre of pest break strip. 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 the biological control agents produced in the pest break strips is many times more than the total listed in Table 4. 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 in pest control costs and the value of the cash crops that can be successfully produced using pest break strips as the principal insect pest management strategy.

Table 4. Value in Dollars Per Acre of Some of the Beneficial Arthropods Produced in Pest Break Strips on the Naturfarm.

Group or Species	Population/Acre of Pest Break Strip (No.)	Individual Cost (\$ U.S.)	Value Per Acre (\$ U.S.)
Lady Beetle (Adults)	200,000	0.0006	125
Lady Beetle (Larvae)	232,000	0.025	5,820
Lacewing Larvae	206,000	0.003	5,071
Spiders	1,000,000	0.003	3,000
Big-Eyed Bugs	401,000	0.003	1,203
Parasitic Wasps	287,000	0.007	2,009
Total Numbers and Value/ Acre	2,326,000	Aver. 0.007	17,208

IV. Management of Pest Break Strips

In 1990, Dietrick confirmed that the vast complexes of beneficial predators and parasites of insect pests known to inhabit strip-cut alfalfa were present in the pest break strips at the Naturfarm. The principal management techniques that produced this result were simply regular irrigation and strip-cutting. Additional management techniques that were evaluated included: 1) seeding pest break strips with commercial insectary reared beneficial insects; 2) selective insect vacuuming to remove pest species and re-release beneficial species; 3) release of new species of classical biological control agents; 4) various methods of gopher control; and 5) varying plant species composition in pest break strips. These and other details of the techniques involved in managing pest break strips are discussed below.

Establishment

Refer to the guidelines given in Section III (Design and Layout). 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. Spring would be next best for planting, and summer the least best. Winter plantings do not work at all. Strips can be planted with a modified grain drill, a billion, or a specialty planter, depending on the mix and the equipment that are available. 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.

Mowing and Strip-Cutting

Strip-cutting is best started in the spring. In a historic and definitive University of California how-to publication on strip-cutting of alfalfa for biological control of Lygus, alfalfa weevil and other pests, Stern et al. (1967) concluded that:

"Strip-cutting works best and is started most easily on the first cutting. In the spring when days are short, alfalfa is slow to go into bloom. At this season, the correct time for cutting can be determined from the new buds at the base of the plant. The first set of strips should be cut when 25 percent of the new shoots are 1/2 to 3/4 inches high. About 10 days later, the second or alternate set of strips should be cut. This will set up a harvesting differential for the second cutting . . . If the alfalfa in the adjoining strips is 6 to 8 inches tall, these females [Lygus] will drift into these plots and remain there. Shorter hay is not as attractive to these drifting Lygus. At cutting time, when the alternate strips have about 10 inches or more regrowth, all of the Lygus are driven from the cut strips to this young succulent hay."

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. So, 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. In the spring, the clovers in the mixture can be managed according to the same guidelines. These criteria will also apply to a newly planted pest break strip.

Scheduling the mowing operations in pest break strips by monitoring flowering activity in the strips is more reliable than using regular calendar intervals. Flowering activity is controlled by plant physiology and the plant's intricate response to the environment. Comparable to using temperature degree-days to predict crop maturity, using flowering activity to schedule mowing operations is linked to phenology, the study of the timing of phenomena occurring in nature as related to environmental conditions. Phenology is becoming increasingly important in IPM programs for biological control of insect pests. Today, local weather station information on degree day accumulations can be interpreted by computer software to help predict pest activities (University of California Statewide IPM Project, 1993). This information can be used to time pest control measures such as setting out monitoring traps, releasing beneficial arthropods, or other measures, such as spraying pesticides.

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. 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.

Once pest break strips are well-established, regular mowing of half the strip every two weeks, starting with the onset of flowering, will work well. Some farmers may be tempted to harvest the alfalfa as forage for livestock. In a mature strip, this practice is fine. However, the chopped plant material that falls and remains in the strip when it is simply mowed and not harvested for forage is an important habitat for many larvae of predatory beetles and bugs. So, again, it is useful to regard the production of beneficial predator and parasites as a livestock operation. In cases where pest break strips are strip-cut and harvested for forage, one or two cuts per season might be mowed and left in the field as a duff to increase production of beneficial insects.