Biologically Integrated Orchard Systems (BIOS) for Almonds in Merced County

Second Edition

June 1994

Robert L. Bugg

Glenn Anderson

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Published by

Community Alliance with Family Farmers Foundation

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Community Alliance with Family Farmers Foundation (CAFF Foundation) is a non-profit, non-governmental organization founded in 1978. The Lighthouse Farm Network, a program of CAFF Foundation, provides support to farmers who are reducing their use of farm chemicals and promotes the adoption of sustainable farming practices. Farmers who join the Network share practical farming information by participating in monthly breakfast and lunch meetings, farm tours, field days, and community outreach events.

Biologically Integrated Orchard Systems (BIOS)
for Almonds in Merced County

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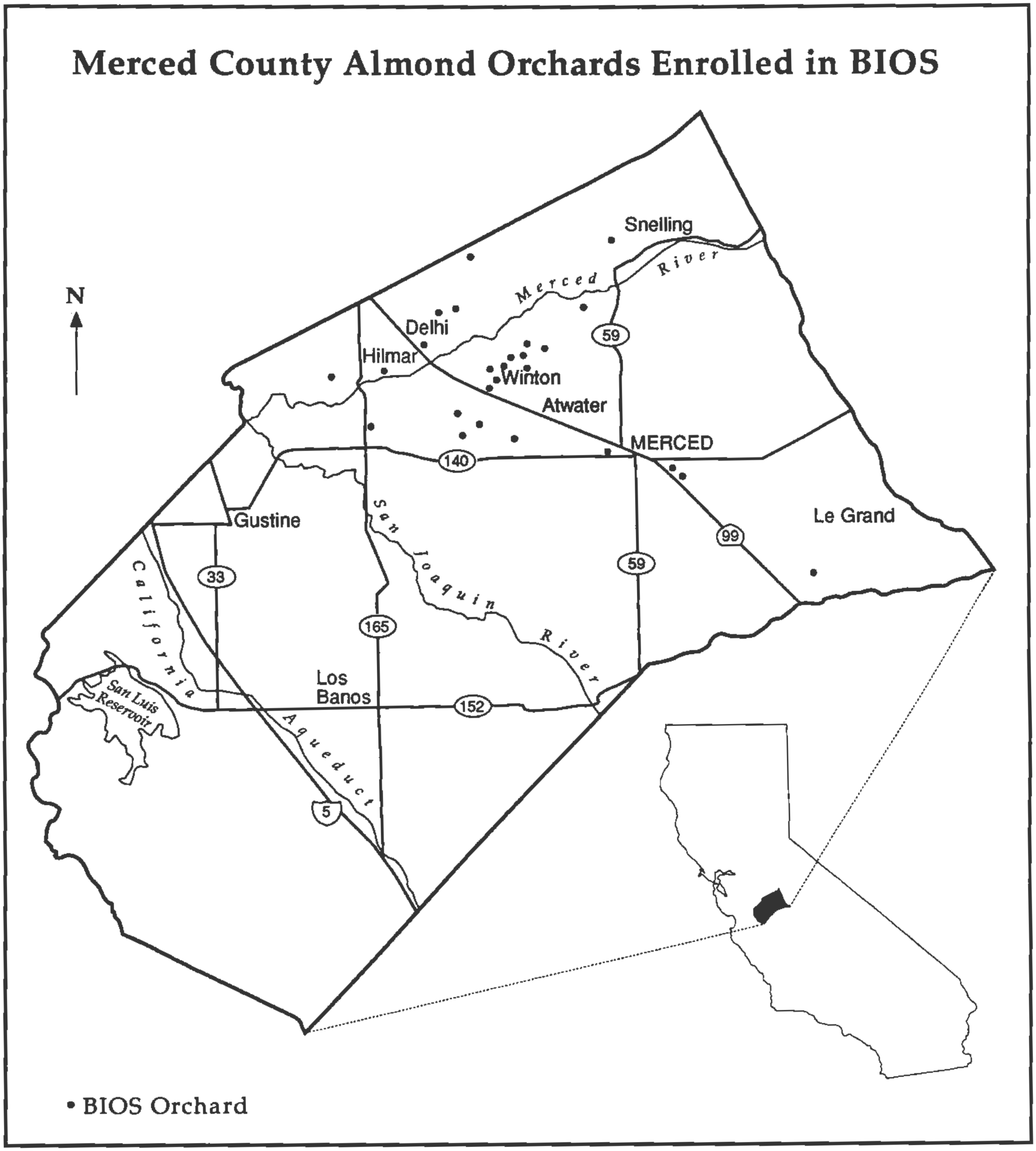
Merced County Almond Orchards Enrolled in BIOS
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Merced River
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Introduction

A new project has been developed to provide technical and financial support to Merced County almond growers who are willing to experiment with reducing chemical fertilizers and pesticides. This project is coordinated and supported financially by the Community Alliance with Family Farmers Foundation (CAFF Foundation). To carry out this project, CAFF Foundation has formed a team of two farmers, the county farm advisor, a pest control advisor, and a UC extension researcher with experience in Biologically Integrated Orchard Systems (BIOS).

BIOS relies more on biological processes than agri-chemicals for cost-effective fertility and pest management. For example, an ongoing comparison of organic and conventional almond orchards by one of us (Hendricks) has confirmed that cover crops can be an important tool in managing almond pests and their natural enemies. Under BIOS management, agri-chemicals are selectively used so they do not interfere with desirable natural processes, and in some cases, to enhance or fine-tune biological subsystems.

We believe this approach is on the cutting edge of agricultural technology and that growers can use these techniques to reduce chemical inputs while maintaining high productivity. As with most forms of ecological agriculture, there is no unique "right way" to farm with BIOS; rather, there are guiding principles, sets of options, and trade-offs to consider (Table 1). Here we present information on BIOS.

Understory Management

As with most other nut crops, almonds are harvested mechanically by shaking nuts to the ground and then sweeping them up. The orchard floor must be smooth and virtually free of residue to allow pickup of the nuts. This requirement has discouraged cover cropping and tillage. Even though cover cropping may increase the likelihood of frost under some conditions, the practice is seeing widespread success in California grape production, and its use is increasing in all types of orchard crops. Based on our experience, some kinds of cover cropping and tillage are clearly compatible with almond production.

Understory cover crops are key components of ecological orchard management because they are useful in maintaining soil fertility and in controlling pests. There is a rich array of cover-cropping options and associated management issues. There are also various ways of considering and categorizing cover crops:

(1) Primary function — nitrogen fixation vs. nitrate scavenging vs. phosphorus facilitation vs. providing precursors for humic substances vs. nematode or pathogen suppression vs. habitat for beneficial insects vs. mixed functions.

(2) Life cycle of the cover crop — annual vs. biennial vs. perennial vs. mixtures.

(3) Mowing and tillage regimes employed by the farmer — green manure (ploughed under) vs. no-

till vs. mowing vs. mixed strip systems of management.
(4) Maintenance — seeded by the farmer annually vs. self-regenerating vs. a combination.
(5) Immediate source of plant materials — domestic cultivars vs. resident vegetation vs. a combination.
(6) Origin of plant materials — true native vs. introduced vs. a combination.
(7) Plant species groups — Fabaceae (legumes) vs. Poaceae (grasses) vs. Brassicaceae (mustard family) vs. mixtures of species from various plant families. Clearly, the way we think about cover crops may affect our choice of plant materials and the way we manage them.

In general, we suggest cover cropping with a mixture of both seeded and resident plant species. Immediately after harvest, in late summer or early autumn, we recommend seeding cool-season cover crops of vetches, medics, or clovers using a broadcast seeder followed by a ring roller or a seed drill. Prompt irrigation ensures quick establishment of cover crops; this usually leads to the most biomass and nitrogen production by spring.

Mowing is an important tool in orchard cover crop management. Mowing can be used to:
(1) Reduce frost problems (close mowing or sprinkler irrigation of a standing cover crop may be used).
(2) Increase air movement and thereby reduce humidity and possible problems with plant diseases.
(3) Reduce weed competition with cover crops (6" mowing in February or early March).
(4) Postpone maturation of cover crops (10-12" high mowing in April or early May).
(5) Rejuvenate cover crops (high mowing + irrigation).
(6) Provide food for earthworms and other decomposers and thereby "jump start" the release of nitrogen.
(7) Provide mulch for beneficial arthropod habitat, weed control, and reduce evaporative loss of soil moisture.
(8) Provide channels and otherwise accommodate flood irrigation (see Table 3).
(9) Kill cover crops (close mowing in late April or in May).
(10) Allow warm-season resident vegetation to emerge through cool-season cover crops.
(11) Force beneficial arthropods to move into trees by reducing the amount of understory habitat.
(12) Provide "habitat edges" for beneficial arthropods at the interface between mowed and unmowed cover crops. Edges are especially rich habitats for many beneficial arthropods.

As suggested above, depending on timing and height, mowing can either kill or rejuvenate plants. Therefore, mowing methodology must be determined carefully. If clovers are used, close mowing to a height of 3-4" in February or early March may be needed to allow the clovers to compete with resident vegetation. Mowing during February or early March reduces understory bloom (e.g. mustards and chickweed), thereby prompting pollinators to concentrate on almond flowers. It may also be used to feed earthworms and other decomposers that assist in nitrogen release to the trees, and which later in the season will ensure the breakdown of cover crop residue. Such early mowing may also extend the life of vegetation, modify the mixture by "liberating" slower-growing species, and reduce lignification of plants. Lignified woody plant residues are slower to decompose and sometimes interfere with almond harvest.

In mid-spring, close mowing may kill annual cover crops that are in full flower. Higher mowing preserves buds on the cover crop plants and permits them to regrow; high mowing before peak blossoming can extend attractiveness to both beneficial and pest arthropods. We suggest that April mowing be fairly high (at least 10"). Experienced BIOS orchardists may want to experiment with the "mow-and-throw" feature that allows mulch produced in the alleys to be placed in the tree rows. Cover-crop mowings deposited in the tree rows serve as weed-suppressive mulch and provide a rich food source for soil-improving earthworms. One of the authors (Anderson) uses the Tri-Max Mower with Sidewinder attachment to flail-chop cover crops and place their residues in the tree rows. Another author (Eck) avoided spring mowing in 1993 in his sprinkler-irrigated orchard. Eck delayed mowing until late summer when preparation for harvest began. He used a modified flail mower to finely chop cover crop residue, thereby aiding in the decomposition process. Because of fungal disease problems, Eck experimented in the spring of 1994 with bloom-time mowing to increase air movement and reduce humidity in the almond canopy.

Either rotary or flail mowers may be used to mow cover crops. Rotary mowers are believed to be gentler on beneficial insects and spiders. Rotary mowers usually have a greater range of height adjustment, and they usually make a cleaner cut, although the clippings are coarser. It is not yet clear how different textures of clippings may influence water conservation, nutrient release, and subsequent use by beneficial insects and spiders.

Tillage usually destroys cover crops, but leaving remnant strips can allow reseeding and provide habitat for arthropods. In BIOS for almonds, we usually restrict tillage to disking or shallow rototilling when preparing the orchard floor for harvest.

What we term "middles management" can be used to maintain a mixture of seeded and resident vegetation. This involves sowing, mowing, or tilling differently in alternating middles or within a given middle. It leads to differing heights, stage of maturity, and plant species composition of adjoining sections of the orchard understory. These differences may be important in maintaining habitat for beneficial insects and in dictating their movement into the trees.

Middles management of cover crops can involve: (1) sowing different cover crops in different middles; (2) mowing middles at different times; (3) tilling middles at different times; and (4) combinations of (1), (2), and (3).

Sowing different mixes can lead to stands with different heights and maturities and presenting various resources to pest and beneficial arthropods. Alternating stands of two mixes could collectively remain attractive to arthropods longer. Middles management allows a grower to achieve multiple goals and balance various aims, such as reducing competition from the cover crop and liberating nutrients for the trees, while maintaining habitat and allowing cover crops to reseed.

Middles management has been successful in several orchard crops besides almonds. Walnut orchardist Russell Lester (Winters, California) mows or tills strips of 'Lana' woollypod vetch and common vetch while leaving alternating remnant strips to reseed the entire alley. After the vetches have matured seed in May, flowering will resume if soil moisture is sufficient. This allows Lester to maintain beneficial insect habitat and reduces the amount of seed that must be purchased the next year.

Vetches present some challenges in sprinkler-irrigated orchards because they can climb and block sprinklers. 'Lana' woollypod vetch is very vigorous and is especially prone to do this. It is also relatively resistant to glyphosate (Roundup®). One solution to this problem is to use glyphosate at a higher rate (up to 2 quarts/acre) and with supplemental surfactant (e.g., 1-2 quarts/acre of spreader/sticker). This approach has worked well against hairy vetch in southern Georgia. Alternatively, growers can make use of common vetch or the hybrid 'Cahaba White' vetch, which is less vigorous and less prone to climb. A non-herbicidal approach to managing vegetation around sprinklers is to mow closely (e.g., with a weed-eater around sprinklers) during late February or early March to favor the lower-growing and non-vining clovers and medics. Eck merely tramples the vetch around sprinklers, whereas Lashbrook has installed extensions on her microsprinklers. Both Eck and Lashbrook have grown vetches for several years and report that there have been no problems. Non-impact sprinklers are less impeded by vetch growth because although the plants may block the stream of water, they will not entwine and entangle the mechanism.

Lester, the walnut orchardist, seeds vetch-based cover crops in the middles (alleys) and subterranean clover and burr medic in the tree rows. The vetches are very competitive against weeds and mowing is not required to encourage them. The shorter-statured subterranean clovers and the burr medic require at least one in-row mowing in the winter (February to mid-March), but fix nitrogen, suppress weeds, and do not interfere with overhead sprinkler irrigation to the same degree that the climbing, twining vetches may. Subterranean clovers tolerate close mowing much better than do vetches. Similar systems are being explored by Eck in Merced almond orchards.

If vetches or subterranean clovers impede a sprinkler head's operation and threaten to reduce throw, the legumes can be suppressed using post-emergent herbicides (consult with your pest control advisor or cooperative extension office for recommended products). Alternatively, various synthetic nitrogen fertilizers when banded in the tree rows will "burn back" legume growth. Mechanical control can be obtained using a weed-eater or a rake.

Prune grower T. Turkovich (Winters, California) sowed alternating alleys to different mixtures. One set of alleys received a mixture of 'Lana' woollypod vetch, common vetch, barley, and oat. The other set of alleys was seeded to a mixture of crimson clover, rose clover, subterranean clovers, burr medic, rattail fescue, and soft chess. From late April on, every third alley is mowed high at two-week intervals. Thus, maturation of cover crops is staggered, and resident warm-season vegetation gradually replaces the cool-season annual plants. Beneficial insects, such as lady beetles, ants, and parasitic wasps, are abundant in the understory vegetation. Since 1991, when this scheme was adopted, outbreaks of two-spotted spider mite have been avoided. Prior to this, in the spring of 1990, cover crops were mowed closely throughout the orchard, leading to a spider mite outbreak.

It is important not to allow winter-annual vegetation to mature and dry all at once because this can cause spider mites to move into the trees. Mowing or tilling under alternate strips of winter annual plants allows staggered development of summer-annual resident vegetation, providing additional habitat for beneficial insects, mites, and spiders.

Proper cover crop species selection and management will lead to good tree nutrition, improved biological and cultural control of pests, and breakdown of plant residues in time for harvest.

Plant Materials

Cover crops may include domestic or wild, resident species, or combinations. Seeded cover crops may include various legumes (clovers, medics, and vetches), as well as certain grasses, such as cereal grains (Tables 3, 4, 5, and 6). Resident vegetation includes plants that most people consider weeds (Table 7). The winter-annual complex may include annual sowthistle, burr medic, chickweed, fiddleneck, Malva (cheese weed), several species of filaree, henbit, pineapple weed, ripgut brome, wild barley, and wild oat. Summer-annuals include common knotweed, common purslane, telegraph weed, redroot pigweed, and little mallow. Perennial resident plants include field bindweed, common bermuda grass, puncture vine, nutsedge, water grass, and johnsongrass.

Different plants have different potential functions in BIOS (as reflected in Tables 4-6). For example, legumes such as clovers, medics, and vetches have symbiotic bacteria in their roots that allow them to "fix" atmospheric nitrogen (see Appendix 1 on legume inoculation). Legume residues typically break down quickly in the soil; the nitrogen is liberated and some becomes available to the almond trees. As shown in Table 6, a cover crop of 'Lana' woollypod vetch can contain 200 lbs of nitrogen per acre or more. Common vetch, hairy vetch, purple vetch, and various clovers and medics typically contain somewhat less nitrogen than does 'Lana' woollypod vetch. Grasses do not usually fix atmospheric nitrogen in their roots, but they are good at taking up nitrate and preventing it from leaching through the soil. Residue of mature grass usually does not break down very rapidly, but when it finally does decompose, its lignin contributes to the humic and fulvic acids that are crucial in maintaining soil fertility. Fiddleneck, mustards, and wild radish are particularly good at taking up soil nitrate; their residues decompose more quickly than residues of mature grass.

Different orchards may require different mixes of cover crops. Components to consider in choosing a suitable cover crop mixture include soil type, spatial niches (i.e. orchard middles, tree rows, and berms), and manager preferences. For the first year of BIOS, we developed several cover crop mixes to meet different requirements. For example, where tall-statured cover crops can be tolerated in orchard middles, the "rich mix" is suggested (Table 8) because of its great diversity of grasses and legumes and its high production of organic matter and nitrogen. Where shorter-statured cover crops are required in the middles, the "low-growing mix" is an alternative (Table 9). Where a microsprinkler system is used, drought-tolerant plant varieties are appropriate outside the arcs of the sprinklers, whereas species with greater moisture requirements can exist within the arcs. Both types of plant are included in the "microsprinkler mix" (Table 10). For drip-irrigated orchards, the options are limited to drought-tolerant varieties, such as those contained in the "dryland mix" (Table 11). Some growers wish to use cover crops within the tree-rows or on flood-irrigation berms. Low-growing, highly mowable varieties, such as those contained in the "tree-row mix" (Table 12), are especially appropriate in such niches. Based on the experiences of growers and their agricultural consultants, customized cover-crop mixes may be developed for particular orchards, reflecting the unique characteristics of each.

Cover Cropping and Cultural Control of Pests

The breakdown of cover crop residues provides a more gradual release of nitrogen than that obtained with synthetic fertilizers. This moderate nitrogen supply may lead to less foliar growth by almond trees during the summer.

Cover cropping can lead to greatly improved water penetration by opening the soil and increasing organic matter and thus water retention. This may improve irrigation efficiency. However, all cover crops require water for growth, and their net effect on the balance sheet may vary with soil type, plant materials, and management technique. Early-maturing winter-annual cover crops may be of special value because they do not compete with trees for water or nutrients. Use of mown cover crop residue as mulch can help retain soil moisture and encourage earthworms.

Cover crops can reduce problems with spider mites. This apparently happens by reducing dust, heat, and moisture stress and by encouraging mite predators. Living understory vegetation may also help retain spider mites that may otherwise move into trees. Burndown with contact herbicides can aggravate mite outbreaks by driving mites into the trees.

Navel orangeworm (NOW) overwinters in almond mummies; if mummies are destroyed, so is the pest. NOW in fallen mummies in a cover crop will usually be killed by moisture and fungi and will be destroyed by close flail mowing. Cover crops speed up the decomposition of unharvested almonds, which otherwise are an overwintering niche for navel orangeworm. This has been shown for soft chess, strawberry clover, and resident vegetation.

Pests Associated with Cover Crops

Pavement ant and southern fire ant damage fallen nuts; these ants may be more abundant in cover cropped orchards. Therefore, prompt pickup of shaken nuts is important in avoiding ant damage. Refer to Table 13 for other arthropod pests of almonds.

Beneficial Insects Associated with Cover Crops

Seeded and resident plants provide habitat for beneficial insects and mites that aid in pest control. We are just beginning to understand how to manage seeded cover crops, resident vegetation, and other "insectary plants" to improve pest control. We do know that various plants can provide important alternative foods that beneficial insects rely on when they are not busy attacking pests. Almond itself provides extrafloral nectar (nectar produced by almond leaves) that is exuded by tiny glands about the junction of the leaf blade and the petiole. Ants and parasitic wasps may be observed feeding at these nectaries from spring through autumn. Other plants may also be important.

Many parasitic and predatory insects feed at the flowers of common knotweed. At least 29 types of these insects have been observed feeding on common knotweed nectar. Beneficial insects, including lady beetles and lacewings, are also found with a honeydew-producing, host-specific aphid, *Aphis avicularis*, and a host specific psyllid (an aphid-like insect), *Aphalara curta*. Fall or winter tillage favors common knotweed, which does not germinate during the spring or summer.

Chickweed flowers from December through March, and it is an important early-season nectar source to various parasitic wasps. One of us (Lashbrook) has obtained *Goniozus legneri* by vacuum-sampling flowering chickweed in orchard understories. It remains to be seen what role chickweed nectar may play in the life cycle of this important parasite of navel orangeworm.

Several plants in the aster family harbor aphids and lady beetles during the spring and early summer. Such plants include annual sowthistle, mayweed, and pineapple weed.

Several plants in the pea family harbor aphids and the lady beetles and lacewings that attack them. Such plants include burr medic, clovers, and vetches. Bigflower vetch, common vetch, and 'Cahaba White' vetch (a hybrid) have extrafloral nectaries on their stipules. Stipules are the tiny leaflets that occur at the bases of flowers and leaves. The extrafloral nectaries attract lacewings, wasps, and predatory ants.

Wax-capped scale insects, scale crawlers, and immobile or slow-moving, soft-bodied insects are susceptible to generalist predators. The predatory mite *Euseius tularensis* attacks spider mites and scale crawlers. It also feeds on windblown pollens of trees and grasses in the winter and spring. This predator can reproduce (for one generation) on a diet of grass pollen alone and thus be well established before pest spider mites become abundant. Cool-season annual grasses that provide usable pollens include annual ryegrass, barley, cereal rye, and soft chess. Flowering periods for these and other grasses are summarized in Table 5.

During the summer, spotted spurge is a source of nectar that is used by various ants and parasitic wasps.

Various types of spiders move into almond trees from cover crops when the latter die or are mown. The most important kinds of spiders appear to be in the families Aegelenidae (funnel-web spiders), Clubionidae (sac spiders), Linyphiidae (line-weavers), Salticidae (jumping spiders), and Theridiidae (comb-footed spiders).

Not all ants are pests of almonds. In fact, *Formica aerata* (commonly called the gray field ant, California gray ant, or crazy ant) and a close relative, *Formica moki*, are generalist predators that appear to be important natural enemies of peach twig borer. The gray field ant often feeds on at the extrafloral nectaries of common vetch and 'Cahaba White' vetch, and also tends cowpea aphid colonies on these two plants. Mature colonies of gray field ant have many queens, so existing colonies could be subdivided for inoculative release. In Washington State pear orchards, this has been done with a closely related species, *Formica neoclara*. Flood irrigation appears to discriminate against gray field ant. It is not clear whether other aspects of understory management can improve biological control of pests by *Formica* spp.

Commercial Insectary Cover Crops

Several commercial fall-sown and spring-sown "insectary crops" are now available in California (Table 15). Several of these plants attract beneficial arthropods. Although none of these have been formally tested in orchard systems, some appear promising.

Perennial Insectary Plants

Some beneficial insects associated with almonds show more affinity for various shrubs and trees than they do for cover crops. For example, comanche lacewing is a generalist predator seldom found in cover crops but often seen at night taking nectar from flowering trees, such as soapbark tree, which flowers from mid-May through mid-June, and bottle tree, which flowers from mid-May through mid-October. Brown lacewings and lady beetles also occur on soapbark trees. Other flowering trees and shrubs that attract large numbers of beneficial insects include the following natives: blue elderberry, coyote brush, California coffeeberry, California lilacs, California wild buckwheat, holly-leaved cherry, mule fat, toyon, and various native willows (Table 16).

Anagrus epos, a key egg parasite of grape leafhopper and western grape leafhopper, occurs in overwintering eggs of leafhoppers that infest wild plants (e.g., *Dikrella californica* on wild blackberry, *D. cockerellii* on wild grape) or cultivated plants (e.g., prune leafhopper on French prune). French prune trees are now being planted alongside California vineyards to enhance biological control. *Anagrus epos* also attacks the leafhoppers that can be problems from spring through early summer on Merced County almonds. It remains to be seen whether overwintering habitat for the parasite will aid control of leafhoppers in almonds.

The Roles Of Decomposers

Decomposers are important in BIOS because they break down plant litter (liberating nitrogen and other plant nutrients) and assist in the development of humus. Categories of decomposers include earthworms, various insects, certain mites, beneficial nematodes, fungi, protozoa, actinomycetes, and bacteria. As an orchard is gradually converted to BIOS management, decomposer abundance and diversity appear to increase. BIOS orchardists have observed that as decomposers become more abundant, plant litter is broken down increasingly rapidly. These observations are supported by numerous scientific studies showing that farms under organic management have higher levels of soil life and more rapid decomposition of cellulose.

Earthworms are among the most obvious decomposers, and they are abundant in several orchards that are now under BIOS management or that are now being converted. Based on our preliminary observations, several BIOS orchards contain high densities of earthworms. Earthworms found in Californian orchards include *Microscolex* sp., *Allolobophora* sp., *Aporrectodea caliginosa* complex, and, occasionally, *Lumbricus terrestris* (the nightcrawler).

Not all earthworms behave the same. There are several generalized feeding strategies: (1) epigeic earthworms feed and live in the organic matter at the surface of the soil, and they burrow horizontally; (2) endogeic earthworms feed and live deeper in the soil, and they burrow horizontally; and (3) anecic earthworms pull plant debris underground, and they burrow vertically. Some earthworms may change feeding strategy based on field conditions.

Earthworms ingest decaying vegetation and digest some of the associated microbes. Their burrows aid in water penetration, and their dung (castings) and exudates lead to the formation of water-stable aggregates -- soil particles that protect important nutrients from leaching and erosion.

Castings are a good indicator of earthworm activity. These can be observed best immediately after irrigation. To increase the number of earthworms, try inoculative release of species that are absent and tailoring cover-cropping, mowing, tillage, and chemical regimes.

As part of the BIOS program in Merced County, several participating growers collected earthworms from their orchards, and these earthworms were identified by specialists Matthew Werner of the U.C. Santa Cruz Agroecology Program and Sam James of Maharishi International University, Iowa.

The endogeic earthworm *Aporrectodea caliginosa* was the most widely-distributed species, having been collected in the orchards of Anderson, Boone, Eck, Hopeton Farms, Kruppa, Stinson, and Thompson. This nominal species is now regarded as a complex of three closely related species (Matthew Werner, pers. comm.). As noted in Appendix 2, *Aporrectodea caliginosa* is frequently encountered in other farming systems. The *Aporrectodea caliginosa* complex has diverse feeding habits, including feeding on soft tissue of plant litter at the soil surface or on dead roots below the soil surface. Past collections by Werner (pers. comm.) showed that *Aporrectodea turgida* is present at Anderson's farm. Werner also noted that specimens of *Aporrectodea caliginosa* from the Stinson, Thompson, and Boone orchards were unpigmented (pale), indicating a strictly below-ground existence. By contrast, specimens from Anderson, Eck, Kruppa, and Hopeton Farms had moderate to heavy pigmentation, suggesting at least occasional above-ground feeding, casting, or travel.

The epigeic species *Lumbricus rubellus* was found only at Anderson's, and the endogeic species *Amynthas diffringens* and *Microscolex dubius* were collected at Hopeton Farms. No anecic earthworms were found, nor have obvious middens (turret-like tops of anecic burrows) been seen at any of the BIOS farms. In light of the apparent lack of anecic earthworms in BIOS orchards, Werner (pers. comm.) has suggested inoculative release of the nightcrawlers *Lumbricus terrestris* or *Aporrectodea longa* to promote more rapid litter incorporation.

It is striking that three of the four species collected recently at BIOS farms (*Aporrectodea caliginosa*, *Lumbricus rubellus*, and *Microscolex dubius*) are renowned as "peregrine" or "wandering" earthworms, because they have often been transported by humans to new locations.

Compost

Compost has been defined as "a mixture of decaying organic matter, such as leaves and manure, used as fertilizer" (Second College Edition, American Heritage Dictionary, 1976). A compost is formed during a biological process that converts organic materials such as manures, leaves, brush chippings, sludge, leaves, paper and food wastes into soil-like material through the action of microorganisms.

In commercial composting operations, various raw materials are mixed together in appropriate ratios and formed into piles. These piles are subsequently turned, watered, and amended as needed. Chemical composition of the raw materials, and the heat, moisture, and oxygen of the piles are monitored and controlled. Commercial composting processes require several weeks, with the precise length depending on the raw materials and management. Because of the heat generated due to the microbial activity, most weed seeds and pathogens are destroyed. A finished aerobic compost will have a uniform color and texture, a mellowed odor similar to that of rich forest soil, and a temperature in the pile of below 85° F. These qualities normally indicate a stable complex of nutrients and microorganisms.

Finished composts differ from the raw materials in consistently having a carbon-to-nitrogen ration of about 15-20 to 1, and in not being susceptible to rapid breakdown and loss of nutrients. Nonetheless, compost is a *direct* source of major and minor nutrients, because further decomposition in the soil solubilizes nutrients and makes them available to plant roots. Composts also differ from the raw materials in having higher concentrations of humic and fulvic acids. These acids are complex organic chemicals derived from the breakdown of lignin in plant residues and from phenolic substances synthesized by microbes. Humic acids are soluble only in alkaline solutions, whereas fulvic acids will dissolve in either alkaline or acid solutions. Both humic and fulvic acids are essential in building cation exchange capacities (CEC) of soils; thus, compost may be an *indirect* source of nutrients. Research by Thompson et al. (1989) suggested that soil organic matter contribution to CEC ranges from 14-56%, depending on the parent materials, clay content, and method of determining CEC.

Humic and fulvic acids also increase water-holding capacities and resiliency of soils and adsorb (bind) herbicide residues and so reduce their toxicity to plants. Many farmers who are transitioning to BIOS add compost to reduce residual herbicide activity, thereby enabling cover crops to grow. The severity of phytopthora and other root rots may be lessened by compost, as has been suggested by studies in avocado orchards. The mechanisms for this suppression are unclear. Composts contain microorganisms, such as fungi, algae, actinomycetes and bacteria that are mainly aerobic. These organisms may improve the decomposition of raw organic matter on the orchard floor.

An application of three tons of composted manure per acre contributes about 100 to 120 lbs. of nitrogen, 150 to 175 lbs. of potash, and 75 lbs. of phosphate. The phosphorus and potash are in forms immediately available to the crop and the nitrogen is held in a slow-release form that is not readily leachable out of the root zone.

In many farming systems, shallow incorporation of compost, e.g., with a spring-tooth harrow, is preferred to merely leaving the material on the surface of the soil. A finished compost can be applied at any time during the crop cycle. To enhance performance by the trees and the cover crop, a fall application is recommended, although any subsequent time through spring would be valuable. Compost may also be applied in June or July about the time cover crops are mowed. The microbes in a live compost will help accelerate the decomposition process so that the orchard floor will be ready for harvest. Some orchardists, such as Russell Lester of Winters, report that composts are especially useful in "jump-starting" soil biology during the early stages of transition to BIOS. Once a healthy cover-cropping program and a vigorous complex of decomposers are in place, compost additions may be less important.

Compost may be made on the farm, especially if the raw organic materials are readily available. When purchasing compost, the grower should know what the raw materials were, what the nutrient analysis of the final product is, and whether the compost is truly finished.

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Tables and Appendices

Table 1. Prototypic annual management plan for an almond orchard under biological management.

Month	Operation	Remarks
August-September	**Develop customized farm plan with BIOS management team. Buy cool-season cover crop seed.**	This late in the summer, cover crop seed may be in short supply. See Tables 8-12 for suggested mixtures of seeded cover crops.
	Prepare orchard floor for harvest at least four weeks in advance.	—
	Almond harvest.	Prompt harvest reduces pest problems, especially ants.
October-November	**Consider spreading compost and other forms of fertilization, such as foliar feeds, after harvest.**	Compost contributes to soil organic matter, adds macro and micro nutrients and enhances soil microbial activity.
	Post-harvest irrigation. If using flood irrigation, we suggest seeding cover crops before the post-harvest irrigation.	If you are using sprinkler irrigation, begin to prepare for planting cover crops.
	Prepare ground before planting cover crops. Rip, disk and float only if necessary. If you are happy with the grade, a shallow cultivation of the soil, with a spring-tooth harrow, is recommended.	Deep ripping may cause root damage. Disk and float to level ground, if necessary. Use the spring-tooth harrow to break the soil crust before planting cover crops and insure a good stand.
	Plant cover crops. Inoculate and then seed cover crops, using a broadcast seeder, followed by a ringroller. A seed drill can be used instead of a broadcast seeder, depending on seed size, irrigation system, etc. Leave unseeded strips in some middles to develop resident vegetation.	In general, vetches do well in middles and subterranean clovers in tree rows. **Inoculating legume seed with fresh, viable rhizobia of the appropriate strains is essential the first time you grow that specific legume in an orchard.** See Appendix 1 on proper inoculation.
	Cover crop irrigation is important to initiate cover crop growth. It is best not to wait for the first rains.	Timely irrigation of cover crops usually leads to earlier and higher biomass production and total nitrogen accumulation.
	Option: Release beneficial insects. Release *Goniozus* and/or *Copidosomoxys plethoricus*.	Release beneficial insects if winter sanitation is not planned.
November-December	**Winter pruning.** Pruning should be done promptly. Consider chipping prunings and using as a mulch.	In a vetch system, it is important to prune while the vetch is still small. Vetch will entwine prunings by February, and can make processing or removal of clippings difficult.

Table 1 (continued).

Month	Operation	Remarks
November-December (continued)	**Option: Shake or knock off mummies from trees.** If necessary, remove mummies, after careful monitoring to determine navel orangeworm populations and parasitism levels.	If navel orangeworm populations are high and *Goniozus* populations are low, winter sanitation will reduce navel orangeworm populations.
mid-January-February	**Option: Mow cover crop if necessary.** Note: With sprinkler irrigation it may be better not to mow. Leave a remnant strip of at least 25% of seeded area unmowed to allow all species to produce mature seed.	Mowing cover crops can serve many purposes including: frost protection, reducing competition from weeds, avoiding cover crop bloom during almond bloom, soil-building by addition of organic matter, and postponing maturation and extending cover crop growth later into the season. Mowing can also modify species mix of cover crops and resident vegetation on the orchard floor. An optimal mowing schedule will depend on several things. For example, which cover crops were planted, soil type, irrigation system, temperature cycles and rainfall in a particular year.
February-early-March	**Mow clovers if they have been planted in tree-row strips.** Except with subterranean clovers, it is important to mow clovers before the flower heads form.	Annual clovers compete poorly with resident vegetation unless winter mowing reduces the competition. Vetches and medics usually need no such encouragement. Flail chopping will help destroy mummy nuts infested with navel orangeworm. There is a variety of options for in-row mowing. Cross-mowing may also be an option. Tilting back the mower or using a rotary mower at this time of year will reduce soil compaction.
	***Bt* application included in bloom and/or nutrient spray.**	*Bt* at bloom time controls peach twig borer.
February-April	**Consider spreading compost and other forms of fertilization.**	Synthetic nitrogen fertilizers should be banded in the tree rows so as not to burn the cover crop nor inhibit its nitrogen fixation potential.
mid-April-July	**Mow when necessary.** Mowing options include strip mowing for mulch and high mowing for regenerating cover crops and driving beneficials into trees.	Annual clover may not need mowing at this time.
	Release beneficial insects. *Trichogramma* wasps and, if necessary, *Goniozus*.	Release *Trichogramma* for the first flight of peach twig borer. Release *Goniozus* if navel orangeworm are present in mummies.

Table 1 (continued).

Month	Operation	Remarks
mid-April-July (continued)	**Mow alternate strips of cover crops** at a height of at least ten inches. If using flood irrigation, mow close to the ground every two-three rows to ease water movement through the orchard. In orchard with flood irrigation, consider raking or blowing residue into tree rows to prevent residue from floating during irrigation.	Mowing of strips may be timed to drive beneficial predatory insects and spiders into the trees, to aid in pest control. Alternating strips of mowed and unmowed vegetation leaves remnant strips for beneficial insect and spider habitat and for reseeding. High mowing permits regrowth of plants. Mulch in tree rows gives some weed suppression, provides a rich food supply for earthworms, and reduces evapotranspiration. Staggered strip mowing permits the gradual emergence of warm-season resident vegetation through the cool-season stubble.
May-June	**Consider spreading compost.**	Compost added at this time can aide in cover crop break down.
	Order cool-season cover crop seed. Anticipate harvest preparation.	Sow cover crops as in year 1. If cover crops produced abundant ripe seed, seeding rates may be reduced.
	Release beneficial insects. Particularly predatory mites and *Trichogramma* wasps.	Spider mites and leafhoppers may be problems at this time of year.
July-August	**Prepare orchard floor for harvest** one-two months in advance. Mow remaining orchard-floor vegetation closely. Till using a spring-tooth harrow, then irrigate to seal soil. For flood irrigated orchards, use a shallow rototiller followed by a roller.	Close mowing must be early enough to permit breakdown of residue. Using a rototiller in flood systems will help preserve shallow feeder roots.
	Release beneficial insects. Release *Goniozus* at early Hull split.	*Goniozus* attacks navel orangeworm larvae.
August-indefinitely (YEAR 2)	**If pre-harvest seeding of cover crops** is desired, inoculate legume seed with appropriate rhizobia bacteria immediately before planting.	If middles are floated, supplemental seeding of inoculated cover crops may be needed.
	Continue Prototypic Plan Cycle.	The system may require fine-tuning and modification from year to year as conditions vary and technologies improve.
August-September	**Almond harvest.**	—

Table 2. Mowing, mulching, and incorporating schedule for flood-irrigated almond orchards. This schedule will enable growers to alleviate problems of excessively slow or fast flow and plant residue accumulation that occurs if varietal direction and flow direction are not the same.

Date	Procedure	
	Without Herbicides	**With Herbicides**
February/March (Early bloom)	If blooming cover crops are competing with almonds for bees, mow understory vegetation to a height of 6 inches, leaving unmowed strips about 3-4' wide. Early mowing may help to feed and "jump-start" decomposers.	Same procedures as without herbicides.
April	Mow as needed before irrigations to facilitate water flow. Before first irrigation, make one pass with the mower close to the tree row in every third row, and move the clippings into the tree row or into the standing cover. The mow-and-throw technique works well. If flow is too slow, mow closely. If irrigation flow is too fast, mow high and preserve tall stubble, or mow closely but allow for regrowth prior to irrigation. High stubble can help to "anchor" plant residue and reduce its movement with irrigation water.	About end of April, after cross mowing, spray 3'-6' strips with appropriate contact herbicides. Leave about 1/4 of the understory unmowed in habitat strips, diamonds, or rectangles.
May	Mow as needed before irrigations to reduce friction or speed up irrigation. Before the 2nd and 3rd irrigations, make one pass with the mower close to the tree row in adjacent rows. After May 15th, mowing may be intensified.	Same as without herbicides.
June	Mow as needed before irrigations to reduce friction or speed up irrigation. Near the end of June, begin preparing the understory for harvest.	Begin mowing in both directions.
August	Touch-up mowing as needed,	Continue mowing as needed.
September	Mow between harvests, if this is needed. Rotary mower works well for this.	Mow between harvests, if this is needed. Rotary mower works well for this.

Table 3. Cover crop species commonly used in cover crop mixes for almond orchards.

Common Names of Plants	Species Names
Bigflower Vetch	*Vicia grandiflora*
'Cahaba White' Vetch	*Vicia sativa* X *V. cordata*
Common Vetch	*Vicia sativa*
Hairy Vetch	*Vicia villosa*
Purple Vetch	*Vicia benghalensis*
Woollypod Vetch	*Vicia villosa* ssp. *dayscarpa* cv 'Lana'
Crimson Clover	*Trifolium incarnatum*
Rose Clover	*Trifolium hirtum*
Subterranean Clover	*Trifolium subterraneum*
Oat	*Avena sativa*
Cereal Rye	*Secale cereale*
Barley	*Hordeum vulgare*
Soft Chess	*Bromus mollis* cv 'Blando'
Burr Medic	*Medicago polymorpha*

Table 4. Californian weeds that harbor alternate hosts or prey of beneficial insects.

Weed	Phytophagous Insects	Seasonal Dynamics of Phytophagous Insects and Notes on Associated Beneficial Arthropods	Source of Information
Annual Sowthistle (*Sonchus oleraceus*)	*Hyperomyzus (Nasonovia) lactucae* (L.) (Formerly *Amphorophora sonchi*) Potato Aphid (*Macrosiphum euphorbiae*) Other aphid species.	*Hyperomyzus(Nasonovia) lactucae* (powdery green with inflated cornicles) and *M. euphorbiae* occur from April through July, and serve as prey to convergent lady beetle (*Hippodamia convergens*. The two generalist aphidiid wasps *Aphidoletes aphidimyza* Rondani and *Aphidoletes meridionalis* Felt are found in this aphid community. A red species occurring on annual sowthistle is toxic to lady beetles.	K.S. Hagen and H. Lange, personal communications.
Burr Medic (*Medicago polymorpha*)	Pea Aphid (*Acyrthosiphon pisum*)	*Acyrthosiphon pisum* can be abundant from March through early May, and sustains reproduction by various lady beetles and syrphid flies. The plant also sustains *Lygus hesperus*, a pest of some orchard crops.	R.L. Bugg, personal observation.

Table 4 (continued).

Weed	**Phytophagous Insects**	**Seasonal Dynamics of Phytophagous Insects and Notes on Associated Beneficial Arthropods**	**Source of Information**
Common Knotweed *Polygonum aviculare*	*Aphis avicularis* Hille Ris Lambers *Aphalara curta* Caldwell (Psyllidae)	*Aphis avicularis* occurs from August through November and sustains reproduction by the ladybeetles *Scymnus* sp., *Hippodamia convergens*, and *Coccinella novemnotata*; and the syrphid *Paragus tibialis*. The host-specific psyllid *A. curta* Caldwell may also be an important prey item to generalist predators.	Bugg et al., 1987 R.L. Bugg, pers. obs.
Pineapple Weed (*Matricaria matricarioides*)	*Brachycaudus helichrysi* Bean Aphid *Aphis fabae* Green Peach Aphid *Myzus persicae*	*Brachycaudus helichrysi* is the predominant aphid. It sustains reproduction by convergent lady beetle (*Hippodamia convergens*) and other Coccinellidae	K.S. Hagen, personal communication. H. Lange, personal communication

Table 4 (continued).

Weed	Phytophagous Insects	Seasonal Dynamics of Phytophagous Insects and Notes on Associated Beneficial Arthropods	Source of Information
Mayweed (*Anthemis cotula*)	*Brachycaudus helichrysi* Bean Aphid *Aphis fabae* Green Peach Aphid *Myzus persicae*	*Brachycaudus helichrysi* is the predominant aphid. It sustains reproduction by convergent lady beetle (*Hippodamia convergens*) and other Coccinellidae. *Lygus sp.* can be abundant on mayweed.	K.S. Hagen, personal communication. H. Lange, personal communication R.L. Bugg, personal observation
Wild Barley (*Hordeum leporinum*)	Bird Cherry - Oat Aphid (*Rhopalosiphum padi*) English Grain Aphid (*Macrosiphum avenae*) Other aphid species.	*Rhopalosiphum padi* predominates. Aphid populations build in February. With flowering, aphids can become extremely abundant in the panicles. Wet weather or heat can devastate populations. Mild weather can permit aphids to survive into May, when wild barley senesces. Various lady beetles and syrphid flies reproduce on these aphids, as does the generalist aphidiid wasp *Diaeretiella rapae*.	M. Van Horn, personal communication.

Table 4 (continued).

Weed	Phytophagous Insects	Seasonal Dynamics of Phytophagous Insects and Notes on Associated Beneficial Arthropods	Source of Information
Wild Oat (*Avena fatua*)	Bird Cherry - Oat Aphid (*Rhopalosiphum padi*) English Grain Aphid (*Macrosiphum avenae*) Other aphid species.	*Rhopalosiphum padi* predominates. Aphid populations build in February. Wet weather or heat can devastate populations. Mild weather can permit aphids to survive into May, when wild oat senesces. Various lady beetles and syrphid flies reproduce on these aphids, as does the generalist aphidiid wasp *Diaeretiella rapae*.	M. Van Horn, personal communication.

Table 5. Flowering (pollen-shedding) periods for grasses in California.

Species	Flowering Period
Annual Ryegrass (*Lolium multiflorum*)	June-August
Barley (*Hordeum vulgare*)	April-July
Blue Wildrye (*Elymus glaucus*)	June-August
California Brome (*Bromus carinatus*)	April-August
Cereal Rye (*Secale cereale*)	May-August
Cultivated Oat (*Avena sativa*)	April-June
Foxtail Fescue (*Vulpia megalura*)	April-June
Meadow Barley (*Hordeum brachyantherum*)	May-August
Ripgut Brome (*Bromus rigidus*)	April-June
Wild Oat (*Avena fatua*)	April-June
Wild Barley (*Hordeum leporinum*)	April-June
Rattail Fescue (*Vulpia myuros*)	March-May
Slender Wild Oat (*Avena barbata*)	March-June

For many grass species, early flowering may occur if moisture is available during the previous summer. Flowering may also be prolonged on moist sites. Flowering of annuals typically ends with the exhaustion of soil moisture. The flowering periods given above were obtained from Munz (1973).

Table 6. Height, above-ground biomass, and above-ground nitrogen contents for selected cover crops grown in monocultural plots. Height and biomass data were taken from a replicated field trial in an organic vineyard, in Hopland, Mendocino County, California, during May, 1991. Nitrogen data are based on pure-stand values and are taken from values in the U.C. S.A.R.E.P. cover crop data base, if these are available.

Cover Crop Name	Height, in., Mean ± S.E.M.*	Above-ground biomass, dry, lbs/a, Mean ± S.E.M.*	Above-ground nitrogen content, lbs/a	Remarks
Burr Medic ('Circle Valley', 'Santiago')	13.75±2.13	7,449±1,641	55-125	Volunteers in Merced orchards. Matures in late April. Tolerates alkalinity. Acid-tolerant rhizobia are required on low-pH soils. 'Santiago' is burrless and earlier maturing than 'Circle Valley'.
Crimson Clover ('Flame')	19.25±6.21	7,547±1,320	44-82	Matures in mid-May. Requires winter mowing to encourage. Tolerates sandy soils and low pH; does not tolerate waterlogged soils.
Rose Clover ('Hykon')	17±1.29	5,486±1,490	45-89	Matures in mid-May. Requires winter mowing to encourage.
'Koala' Subterranean Clover	18±1.15	8,617±1,436	180	Tallest subclover, matures in mid-May; tolerates alkaline soils. Requires winter mowing to encourage.
'Mt. Barker' Subterranean Clover	14.5±1.04	6,806±883	224	This late-maturing variety ripens seed in June. Requires winter mowing to encourage.
'Seaton Park' Subterranean Clover	14.75±0.94	6,074±338	N.A.**	Late-maturing variety. Requires winter mowing to encourage.
'Dalkeith' Subterranean Clover	12.5±0.5	4,576±1,641	N.A.**	Early-maturing, low statured and low biomass. Requires winter mowing to encourage.
'Trikkala' Subterranean Clover	17.25±0.63	7,386±1,222	200	Tolerates flooding and heavy soils. Mid-May maturation.
Common Vetch	21.5±1.19	7,948±847	120	Matures in late May and early June. Extrafloral nectaries and cowpea aphid attract beneficial insects.

* Standard error of the mean.

** N.A. = Not available

Table 6 (continued).

Cover Crop Name	Height, in., Mean ± S.E.M.*	Above-ground biomass, dry, lbs/a, Mean ± S.E.M.*	Above-ground nitrogen content, lbs/a	Remarks
Purple Vetch	22.5±1.76	9,028±482	45-268	Matures in late May and early June. Tolerates heavy soils.
Woollypod Vetch ('Lana')	26.5±1.66	8,189±830	45-223	Matures in mid-May. Best N-fixer of the self-reseeding winter annual legumes.
Annual Ryegrass	36.25±1.65	7,591±2,908	45-210	Matures in late May to early June. May compete with almonds for water and N.
Barley ('U.C. 476')	37.25±2.43	11,5433±2,355	32-93	Matures in late April. Tolerates drought and salinity, but not waterlogging.
Cereal Rye ('Merced')	58.5±2.99	8,814±1,597	34	Matures in early May. Tolerates waterlogged soils. Residue is lignin-rich and slow to break down.
Foxtail Fescue ('Zorro')	23.75±4.96	6,682±776	N.A.**	Matures by late April. Tolerates drought and sandy soils. Does not support vetches.
Oat ('California Red')	43±1.47	11,178±1,276	11	Matures by mid May. This cv lodges easily. Other cvs ('Ogle,' 'Swan,' 'Cayuse') produce more biomass and support vetches better.
Soft Chess ('Blando')	39.75±0.85	8,430±1,285	N.A.**	Matures by late April. Tolerates drought and sandy soils. Does not support vetches.

* Standard error of the mean.
** N.A. = Not available

Table 7. Resident vegetation species in almond orchards.

Category	Common Names	Species Names
Winter-annuals	Annual Sowthistle	*Sonchus oleracea*
	Burr Medic	*Medicago polymorpha*
	Chickweed	*Stellaria media*
	Fiddleneck	*Amsinckia intermedia*
	Filaree	*Erodium* spp.
	Henbit	*Lamium amplexicaule*
	Pineapple Weed	*Matricaria matricarioides*
	Ripgut Brome	*Bromus rigidus*
	Wild Barley	*Hordeum leporinum*
	Wild Oat	*Avena fatua*
Summer-annuals	Common Knotweed	*Polygonum aviculare*
	Common Purslane	*Portulaca oleracea*
	Horseweed	*Conyza canadensis*
	Redroot Pigweed	*Amaranthus retroflexus*
	Little Mallow	*Malva parviflora*
Perennials	Field Bindweed	*Convolvulus arvensis*
	Common Bermuda Grass	*Cynodon dactylon*
	Johnsongrass	*Sorghum halepense*

Table 8. Suggested "rich mix" of annual seeded cover crops for middles of almond orchards. Seed at 65 lbs/seeded acre.

Cover Crop	Percentage By Weight In Mixture
Woollypod Vetch ('Lana')	41.5%
Common Vetch or 'Cahaba White' Vetch	15.4%
Barley ('U.C. 476') or Arizona variety	5.2%
Cereal Rye ('Merced')	5.2%
Oat ('Ogle' or 'Swan')	5.2%
Oat ('Cayuse')	5.2%
Oat ('Montezuma')	5.2%
Crimson Clover 'Flame'	5.2%
'Santiago' Burr Medic	5.2%
'Koala' Subterranean Clover	2.2%
'Karridale' Subterranean Clover	2.2%
'Trikkala' Subterranean Clover	2.2%

Table 9. Suggested "low-growing mix" for middles of almond orchards. Seed at 40 lbs/seeded acre.

Cover Crop	Percentage By Weight In Mixture
Common Vetch	39.3%
'Santiago' Burr Medic	19.8%
'Flame' Crimson Clover	4%
'Hykon' Rose Clover	4%
'Koala' Subterranean Clover	7.7%
'Trikkala' Subterranean Clover	7.7%
'Woogenellup' Subterranean Clover	7.7%
'Blando' Brome	9.7%

Table 10. Suggested "microsprinkler mix" for middles of almond orchards. Seed at 35 lbs/seeded acre.

Cover Crop	Percentage By Weight In Mixture
Common Vetch or 'Cahaba White' Vetch	25%
'Flame' Crimson Clover	12.5%
'Hykon' Rose Clover	12.5%
'Santiago' Burr Medic	12.5%
'Dalkeith' Subterranean Clover	5%
'Koala' Subterranean Clover	5%
'Nungarin' Subterranean Clover	5%
'Trikkala' Subterranean Clover	5%
'Woogenellup' Subterranean Clover	5%
'Zorro' Fescue	5%
'Blando' Brome	7.5%

Table 11. Suggested "dryland mix" for middles of almond orchards on drip irrigation systems. Seed at 30 lbs/seeded acre.

Cover Crop	Percentage By Weight In Mixture
'Hykon' Rose Clover	20%
'Santiago' Burr Medic	20%
'Dalkeith' Subterranean Clover	8%
'Koala' Subterranean Clover	8%
'Nungarin' Subterranean Clover	8%
'Trikkala' Subterranean Clover	8%
'Woogenellup' Subterranean Clover	8%
'Zorro' Fescue	8%
'Blando' Brome	12%

Table 12. Suggested "tree-row mix" of annual seeded cover crops. Seed at 28 lbs/seeded acre.

Cover Crop	Percentage By Weight In Mixture
Burr Medic ('Circle Valley' or 'Santiago')	25%
'Koala' Subterranean Clover	25%
'Mt. Barker' or 'Karridale' Subterranean Clover	25%
'Trikkala' Subterranean Clover	25%

Table 13. Arthropod pests of almonds.

Common Names	Species Names
Alder Lacebug	*Corythucha pergandei*
San Jose Scale	*Quadraspidiotus perniciosus*
Navel Orangeworm	*Amyelois transitella*
Peach Twigborer	*Anarsia lineatella*
Oriental Fruit Moth	*Grapholita molesta*
Southern Fire Ant	*Solenopsis xyloni*
Pavement Ant	*Tetramorium caespitum*
Brown Almond Mite	*Bryobia praetiosa*
European Red Mite	*Panonychus ulmi*
Peach Silver Mite	*Aculus cornutus*
Two-Spotted Spider Mite	*Tetranychus urticae*

Table 14. Predatory and parasitic arthropods commonly found in almond trees.

Common Name or Description	Scientific, Generic, or Family Names
Minute Pirate Bug	*Orius tristicolor*
Assassin Bugs	*Zelus renardii* and others
Comanche Green Lacewing	*Chrysoperla comanche*
Common Green Lacewing	*Chrysoperla carnea*
Black-Horned Lacewing	*Chrysopa nigricornis*
Brown Lacewings	*Hemerobius pacificus, H. ovalis,* and others
Lady Beetles	*Hippodamia convergens, Olla v-nigrum, Scymnus* spp., *Stethorus* sp. and others
Wasp Parasite of Navel Orangeworm	*Copidosomoxys plethoricus*
Wasp Parasite of Navel Orangeworm	*Goniozus legneri*
Crazy Gray California Field Ant	*Formica aerata*
Western Predatory Mite	*Galandromus occidentalis*
Predatory Mites	*Euseius tularensis,* and others
Funnel-Web Spiders	Aegelinide
Orb-Weaver Spiders	Araneidae
Sac Spiders	Clubionidae
Line-Weaver Spiders	Liniphiidae
Jumping Spiders	Salticidae
Comb-Footed Spiders	Theridiidae
Crab Spiders	Thomisidae

Table 15. Species compositions of commercial insectary seed mixes.

Seed Company and Name of Mix, if available	Common Names of Plants in Mix	Species Names
Clyde Robin Seed Company,	Evening Primrose	*Oenothera argillicola*
Hayward, California	California Buckwheat	*Eriogonum fasciculatum*
"Border Patrol"	Baby Blue Eyes	*Nemophila menziesii*
	Candytuft	*Iberis umbellatum*
	Bishop's Flower	*Ammi majus*
	Black-Eyed Susan	*Rudbeckia hirta*
	Strawflowers	*Helichrysum* sp.
	Nasturtiums	*Nasturtium* sp.
	Angelica	*Angelica* sp.
	Yarrow	*Achillea millefolium*
Lohse Mill Inc., Artois,	Yellow Sweetclover	*Melilotus officinalis*
California	White Sweetclover	*Melilotus alba* cv 'Hubam'
Fall-Sown Insectary Mix	Common Vetch	*Vicia sativa* L.
	Subterranean Clovers 3-4 varieties	*Trifolium subterraneum*
	Crimson Clover	*Trifolium incarnatum*
	Alfalfa	*Medicago sativa*
	Rye	*Secale cereale*
	Barley	*Hordeum vulgare* cv 'U.C. 476'
	White Mustard	*Sinapis alba*
	Brown Mustard	*Brassica juncea*
	Yarrow	*Achillea millefolium*
	Baby Blue Eyes	*Nemophila menziesii*
	Sweet Alyssum	*Lobularia maritima*
	Baby's Breath	*Gypsophila muralis*
	Tidy Tips	*Layia platyglossa*
	Carrot	*Daucus carota* L.
	Coriander	*Coriandrum sativum*
	Sweet Fennel	*Foeniculum vulgare* var. *dulce*
	Celery	*Apium graveolens*

Table 15 (continued).

Seed Company and Name of Mix, if available	Common Names of Plants in Mix	Species Names
Lohse Mill Inc., Artois,	Buckwheat	*Fagopyrum esculentum*
California	Cowpea	*Vigna unguiculata ssp. unguiculata*
Spring-Sown Mix		
	Sorghum	*Sorghum bicolor*
	Sesbania	*Sesbania exaltata*
Germain's Incorporated,	Birdsfoot Trefoil	*Lotus corniculatus*
Fresno, California	Sweet Alyssum	*Lobularia maritima*
	Yarrow	*Achillea millefolium*
	Baby Blue Eyes	*Nemophila Menziesii*
	Poppy	*Eschscholzia californica* Cham.
	Little Burnet	*Sanguisorba minor*
	Buckwheat	*Fagopyrum esculentum* Moench
	Crimson Clover	*Trifolium incarnatum*
Pacific Coast Seed,	Annual White Sweetclover	*Melilotus alba* cv 'Hubam'
Pleasanton, California	Yellow Sweetclover	*Melilotus officinalis*
	Coriander	*Coriandrum sativum*
	Parsley	*Petroselinum crispum*
	Caraway	*Carum carvi*
	Fennel	*Foeniculum vulgare* var. *dulce*
	White Yarrow	*Achillea millefolium*
	White Cosmos	*Cosmos bipinnatus*
	Dwarf White Sweet Alyssum	*Lobularia maritima*
	Tall White Sweet Alyssum	*Lobularia maritima*
	Annual Baby's Breath	*Gypsophila muralis*
	Tidy Tips	*Layia platyglossa*

Table 15 (continued).

Seed Company and Name of Mix, if available	Common Names of Plants in Mix	Species Names
Peaceful Valley Farm	Crimson Clover	*Trifolium incarnatum*
Supply, Grass Valley	Rose Clover	*Trifolium hirtum*
"Good Bug Blend"	White Clover	*Trifolium repens*
	Alfalfa	*Medicago sativa*
	Baby's Breath	*Gypsophila* sp.
	California Buckwheat	*Eriogonum fasciculatum*
	White Alyssum	*Lobularia maritima*
	Nasturtium	*Nasturtium* sp.
	Yarrow	*Achillea millefolium*
	Carrot	*Daucus carota*
	Dill	*Anethum graveolens*
	Daikon Radish	*Raphanus sativa*
	Celery	*Apium graveolens*
	Radish	*Raphanus sativa*
	Caraway	*Carum carvi*
	Chervil	*Anthriscus cerefolium*
	Parsley	*Petroselinum crispum*
	Coriander	*Coriandrum sativum*
Harmony Farm Supply,	Annual White Sweetclover	*Melilotus alba* cv 'Hubam'
Graton, California	Yellow Sweetclover	*Melilotus officinalis*
"Insectary Blend"	Coriander	*Coriandrum sativum*
	Parsley	*Petroselinum crispum*
	White Yarrow	*Achillea millefolium*
	White Cosmos	*Cosmos bipinnatus*
	Dwarf White Sweet Alyssum	*Lobularia maritima*
	Tall White Sweet Alyssum	*Lobularia maritima*
	Annual Baby's Breath	*Gypsophila muralis*
	Tidy Tips	*Layia platyglossa*

Table 16. Perennial insectary plants.

Common Names	Species Names
Blue Elderberry	*Sambucus caerulea*
Bottle Tree	*Brachychiton populneus*
Bronze Fennel	*Foeniculum vulgare*
California Coffeeberry	*Rhamnus californica*
California Lilacs	*Ceanothus* spp.
California Wild Buckwheat	*Eriogonum fasciculatum*
Coyote Brush	*Baccharis pilularis*
Creeping Boobialla	*Myoporum parvifolium* 'Davis'
Hollyleaf Cherry	*Prunus ilicifolia*
Mule Fat	*Baccharis viminea*
Narrowleaf Milkweed	*Asclepias fasicularis*
Native Willows	*Salix* spp.
Soapbark Tree	*Quillaja saponaria*
St. Catherine's Lace	*Eriogonum giganteum*
Toyon	*Heteromeles arbutifolia*
Yarrows	*Achillea* spp.

Table 17. Flowering Periods of Selected Insectary Plants.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Willow species	■	■	■	■								
Ceanothus species		■	■	■	■							
Mule Fat			■	■	■							
Yarrow species				■	■	■	■					
Coffeeberry				■	■							
Holly Leaf Cherry				■	■							
Soapbark Tree					■	■						
Buckwheat species					■	■	■	■	■	■	■	■
Elderberry species					■	■	■	■	■			
Toyon					■	■						
Myoporum						■	■	■	■	■		
Bottletree							■	■	■	■		
Fennel							■	■	■			
Narrowleaf Milkweed							■	■	■			
Coyote Bush	■									■	■	■

Appendix 1: Inoculating and Establishing Legumes

Many legumes fix nitrogen when grown with symbiotic bacteria called rhizobia, which are housed in root nodules. The legume provides sugars and minerals to the rhizobia, which respond by helping the plant change atmospheric nitrogen to a form usable by the host plant. This is called nitrogen fixation. An essential link in this pathway is the chemical leghemoglobin, produced by the plant. If the nodules appear pink inside, that indicates leghemoglobin, and nitrogen fixation has almost certainly been occurring. Amino acids produced by the rhizobia are converted to protein and other substances and stored by the plant. Leguminous crop residues are decomposed in the soil, and some of the nitrogen soon becomes available to succeeding crop plants.

In order to ensure that the collaborative relationship is successful, legume seed should be inoculated with the proper rhizobia prior to sowing. Just any rhizobial strain won't do, so make sure that package of the strain sent to you specifically lists the cover crop for which you intend it. For example, the rhizobial strain that is compatible with both rose clover and subterranean clover (type WR) will not work for crimson clover (type R), burr medic (Special Culture No. 1 for Medicago) or vetches (Type C).

Bacteria for inoculant are cultured in the laboratory and sold in a carrier made of peat moss. The bacteria are delicate. It is important to keep the inoculant relatively cool, and to avoid placing it in direct sunlight. Ultraviolet rays from sunlight will quickly kill the delicate bacteria. So will antimicrobial seed treatments (e.g., most fungicides and some insecticides). Expiration dates are usually stamped on the plastic bags, indicating the limits of viability. These dates should be carefully observed.

It is also important to use an adhesive nutrient gel as a sticker. PEL-GEL is the proprietary material marketed by Nitragin Corporation, and it is highly recommended by University of California researchers who have compared its use in inoculation to other methods. The following are steps to ensure proper inoculation and the establishment of a vigorous, nitrogen-fixing cover crop.

Inoculation and establishment are the stages where many beginners err when trying to grow cover crops, so pay special attention to the steps.

(1) About 6 lbs of dry weight PELINOC-PELGEL materials (rhizobial inoculant and sticker) are added per 100 lbs of legume seed.

(2) Mix the nutrient gel with a little unchlorinated water until you get a tacky paste.

(3) Add some of the inoculant and stir it in.

(4) When the inoculant and the paste are thoroughly mixed, add water a little at a time, to get a more dilute suspension.

(5) When the recommended amount of water has been added, pour just enough of the suspension over the seed to wet it.

(6) Pour the remaining dry inoculant over the damp seed, and mix thoroughly. The dry inoculant will absorb the excess moisture.

(7) Now the seed is coated with delicate, living bacteria. Once it has been allowed to dry in a cool, shady location, it will be ready to be sown. Avoid placing inoculated seed in sunlight, or in hot or dry locations, because the rhizobia are easily killed. Also avoid delays in sowing freshly-inoculated seed.

(8) Do not delay planting of cover crops. The earlier in autumn you establish a cool-season cover crop, the better stand you will get, and the fewer weeds. See Tables 7-11 for suggested seeding mixtures.

(9) Prepare a good seedbed by disking; broadcast seed; incorporate seed using a ring-roller. Seed for clovers and medics should be incorporated no deeper than 1/2 inch. Vetch seed does well when incorporated to a depth of 1/2 inch, but may be planted as deep as 1 inch.

(10) Irrigate cover crops immediately after seeding and before weather turns cold, to ensure quick establishment and success of the nitrogen-fixing symbiosis.

(11) Annual clovers often benefit from mowing at least once from February through mid-March. This reduces competition by weeds. Vetches usually do not require mowing.

(12) Avoid applying nitrogen fertilizers to living legumes. The fertilizer will burn the legume foliage and reduce any competitive advantage that legumes may have over non-nitrogen fixing plants. If nitrogen fertilizers must be used, restrict their application to a narrow band within the tree row.

Vetch and other large-seeded legumes are seldom sold pre-inoculated. When seeding mixtures of vetches and pre-inoculated medics or clovers, an appropriate procedure is to layer the dry inoculant and the cover crop seed within the boxes of the seeder. One bag of "Type C" inoculant poured atop each 100 lbs of seed would be an appropriate rate. The agitation caused by the seeding process will cause the powdered inoculant to sift among the seed, and it will be metered and incorporated into the soil along with the seed.

Appendix 2: Earthworms

Earthworms are increasingly recognized not only as indicators of agroecosystem health, but also as important tools for ensuring soil improvement and efficient nutrient cycling. In the past, U.C. S.A.R.E.P. has highlighted both historical and recent research on earthworms (Werner et al., 1990 and Werner, 1990). The literature has since proliferated rapidly; here we present additional findings from more recent or underexposed research, and include observations from an ongoing demonstration project (Biologically Integrated Orchard Systems: BIOS).

Tillage Effects

Parmelee et al. (1990) conducted a "piggyback" study in long-term research plots at Horseshoe Bend in north-central Georgia. The long-term trial involved a sandy clay loam soil planted to a soybean-cereal rye-sorghum rotation and managed with vs. without tillage. *Aporrectodea caliginosa* was the dominant annelid earthworm, and *Lumbricus rubellus* was also present. No-till management led to a 1.42-fold increase in annelid density and biomass over those observed with conventional tillage. Detailed sampling indicated that densities of Enchytraeidae (a family of small earthworms) were higher under no-till, which contradicted earlier preliminary sampling of the same plots (Hendrix et al., 1986). When the vermicidal pesticide carbofuran was imposed on the long-term treatments, it resulted in a 47% increase in particulate organic matter under the no-till regime.

Organic Matter and Nitrogen Cycling

Kretschmar and Ladd (1993) conducted a laboratory study of the decomposition of subterranean clover (*Trifolium subterraneum*) foliage incubated in columns of loamy sand. Clover foliage was incorporated at varying depths and soil was compacted at varying pressures. The earthworm *Aporrectodea trapezoides* was then added to some columns, but not to others. Results suggested that if herbage was deeply incorporated or the soil highly compacted, the earthworm alleviated the problems of decreased oxidation rates, and thereby promoted decomposition of the residues.

Ruz Jerez et al. (1988) conducted a study on organic matter breakdown and nitrification as influenced by the earthworms *Lumbricus rubellus* or *Eisenia fetida*. The study was conducted in laboratory glass incubation chambers (2 liter capacity). Into these were introduced soil (fine sandy loam, Dystric eutrochrept, mixed mesic), earthworms (10 per chamber [reviewer's note: this would correspond to high field densities]). Dried wilted or senescing clover or grass residue was incorporated into the upper 1 cm of soil in each chamber. Following an initial amount of litter that would correspond to 700 kg DM/ ha, additional litter was added at a rate of 350 kg DM/ha-week, for 10 weeks thereafter. The total addition of clover or grass herbage during the 77 days of the study was 4,200 kg DM/ha (reviewer's note: this total is about the amount of organic matter that would result from one fairly close mowing of an cover crop of annual grasses, clovers, or medics in a Californian orchard). The researchers observed an approximately 50% increase in mineral N after 77 days incubation with earthworms as compared to without; mineral N was 9% higher in chambers that were held at 22.5C than in those that were held at 15C. When results with earthworms were pooled over both temperatures, only 0.6% of the clover residue remained, whereas 9% of the grass residue was recoverable; this is probably related to difference in C:N ratio as well as to palatability to earthworms. In chambers without earthworms, 11.3% of the clover residue remained, and 13.7% of the grass residue. Microbial biomass was reduced in chambers with earthworms. No information was presented comparing results obtained for *Lumbricus rubellus* vs. *Eisenia fetida*. Test plants (ryegrass [*Lolium* sp.]) grown in the various treatments following incubation suggested a 25% in N uptake following incubation of herbage and soil with, as opposed to without, earthworms. The authors suggested that prior laboratory studies may have underestimated earthworm respiration rates.

Marinissen and de Ruiter (1993) assessed data on the cycling of nitrogen and organic matter from a study at the Noordoostpolder, Marknesse, Netherlands, and from the long-term study in Horseshoe Bend, Georgia (described earlier under Parmelee et al., 1990). As in the Horseshoe Bend study, the dominant annelid at the Netherlands site was *Aporrectodea caliginosa* (constituting 92% of the wet biomass of annelids). Other species observed at the Noordoostpolder were *Lumbricus rubellus* (6%) and *Aporrectodea rosea* (2%). The researchers developed projections for nitrification based on both direct and indirect effects of earthworms. Direct effects were calculated based on varying assumptions concerning production rates of dead tissue, casts, urine, and mucus. Other assumptions that were varied concerned the C:N ratios of the earthworms themselves and of the organic matter being processed. Indirect effects of earthworms were also evaluated, based on the possibilities that: (1) increased grazing by earthworms on microbes stimulates microbial regrowth, and (2) that earthworm-induced improvement of soil structure promotes microbial activity. Projections from the Noordoostpolder data suggested that earthworms are directly or indirectly responsible for nitrification of from 10-100 kg N/year. Data from Horseshoe Bend, where earthworm densities were higher, suggested corresponding figures of from 82-364 kg N/year. These widely varying projections reflect a need for more precise assessment of the parameters employed in the models.

Soil Structural Changes

Lee and Foster (1991) composed a review article suggesting that earthworm burrows are important for water infiltration only when irrigation or rainfall exceeds the soil capacity for capillary uptake. Moreover, anecic earthworms may block burrow entrances with soil or plant material, or position their bodies to obstruct flow down the burrows. Any of these phenomena make earthworm burrows less effective in promoting water infiltration. The presence of clay-organic matter complexes promote soil aggregate stability; earthworm casts are frequently more stable, but are sometimes less so than are other soil aggregates. The authors gave no explanation for this discrepancy.

Zhang and Schrader (1993) conducted laboratory studies on the aggregate stability of "natural," worm-induced, and pressure-induced aggregates. Worm-induced aggregates from castings and burrow linings were less stable than "natural" aggregates, but more so than those formed by human agency through mere compression. The authors considered it unlikely that earthworms rupture mineral particles by compression, but did suggest the rupture of chemical bonds following earthworm ingestion of "natural" aggregates. The tensile strength (resistance to crushing) of aggregates formed by the three species of earthworms assessed was as follows: *Lumbricus terrestris* > *Aporrectodea longa* > *Aporrectodea caliginosa*. Tensile strength was positively correlated with organic matter content in the worm-formed aggregates.

Toxicology

Martin (1986) conducted a toxicological study that indicated that *Aporrectodea caliginosa* is as sensitive or more so to pesticides than are other agriculturally important earthworms. The author suggested that this species would be a logical choice for screening pesticides intended for use in pasture crops or crops grown in rotation with pasture.

Fertilizers

Ma et al. (1990) assessed the effects of turf-grass fertilization with six types of nitrogenous fertilizers, including mineral ammonium sulfate, nitrochalk (ammonium nitrate with lime), sulfur-coated urea, organic-coated urea, isobutylidene-diurea, and ureaformaldehyde. There were three rates of application for each of the 6 fertilizers, corresponding to 60, 120, and 180 kg N/ha-yr. The trial was carried out in a loamy sand soil in Haren, Netherlands, on a turf that included various annual and perennial grasses. Plots were 2.5 X 3.0 m and arrayed in a randomized complete block with 2 replications for each of 18 treatments. Results suggested profound reductions caused by ammonium sulfate and by sulfur-coated urea in the endogeic earthworms *Aporrectodea caliginosa caliginosa* and *Aporrectodea rosea*. By contrast, the edogeic earthworm *Aporrectodea caliginosa tuberculata* and the epigeic *Lumbricus rubellus* showed less reduction. The observed reductions were believed by the authors to have been caused by acidification. *Aporrectodea caliginosa tuberculata* and *Lumbricus rubellus* have in the past been noted as tolerant of acid soils, whereas the types of worms showing reductions have been regarded as doing best near neutral pH. Nitrochalk had little effect on earthworm densities, and the other fertilizers had intermediate effects.