BIOLOGICALLY INTEGRATED ORCHARD SYSTEMS (BIOS) FOR ENGLISH WALNUTS: OPTIONS FOR COVER CROPPING

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Biologically Integrated Orchard Systems (BIOS) have been developed by farners, scientists, and agricultural consultants, in collaboration with the Community Alliance with Family Farmers Foundation of Davis, California. Such systems are now in use for several Californian tree crops, including almonds, prunes, and English or Persian walnuts.

As with most other nut crops, walnuts are harvested mechanically by shaking nuts to the ground and then retrieving them. The orchard floor must be smooth and free of debris to allow pickup of the nuts. This makes cover cropping more difficult, but it is still practical, and is being used increasingly in all types of orchard crops.

Understory cover crops are key components of ecological orchard management, because they are useful both in maintaining soil fertility and in controlling pests. In general, cover cropping is most practical under sprinkler or flood irrigation. Drip systems present problems, because seeded cover crops in the middles must rely on unreliable rainfall. Moreover, walnuts present some special problems:

1) Dense shade in many orchards interferes with establishment and early growth of cover crop seedlings.

2) Standard harvest preparation damages seedlings, particularly legumes. Legumes have growth points (meristems) that are relatively high on the plant (apical and lateral meristems), whereas grasses have growth points that are flush with the soil (intercalary meristems). Therefore, grass seedlings typically recover more quickly from close mowing.

3) Relatively late harvest (late October and November) means that seedlings must establish afterwards in cold weather, which is more favorable for grasses than for legumes. Various cool-season annual rasses can grow at lower temperatures than can winter-annual legumes. Also, slugs and other herbivores that are active in cold, wet weather are more likely to damage seedlings during November and December than during September and October, when almond orchards are ready for seeding.

4) Deep leaf litter appears to inhibit the establishment of some cover crops, including various clovers and burr medic. Of the legumes BIOS growers have tried, common vetch appears to establish best through deep walnut leaf litter.

Some scientists believe that juglone, a chemical produced in walnut tissues, interferes with growth of various plants. However, recent studies suggest that shading is much more important in suppressing understory vegetation. This corresponds with BIOS growers' observations that where pruning or tree spacing leads to well-lit orchard floors, late-sown winter-annual legumes grow much better.

Drip- or microsprinkler-irrigated orchards may have problems in preparing for harvest, because cover crop leaf litter is slow to break down in dry conditions.

Plant material selection is an important cover-crop management issue. In general, we suggest cover cropping with a mixture of both seeded and resident plant species. We use mixtures of legumes and grasses, with varying heights, statures, and biomass production (see Table 1 and Appendix 2). In sprinkler- or flood irrigated orchards, 'Lana' woollypod vetch, common vetch, burr medic, crimson clover, and subterranean clovers may be grown in mixtures or in bands. Grasses that appear useful include barley, cereal rye, and oat. In drip-irrigated orchards, burr medic and 'Lana' woollypod vetch are the most viable options. We prefer legume-dominated stands and try to limit grasses so that they represent no more than about 10% of the vegetational cover. This will maximize N-fixation and minimize problems of excessive residue at harvest.

Immediately prior to or after harvest in late summer or early autumn, we recommend inoculating seed of winter-annual clovers, bur medic, and vetches (see Appendix 1), and seeding using a seed drill, or a broadcast seeder followed by a ring roller. In sprinkler- or flood-irrigated orchard, prompt irrigation ensures quick establishment of cover crops; this usually leads to the most biomass and nitrogen production by spring.

Plant Materials

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

Different irrigation systems, soil types, spatial niches, and manager preferences may dictate different mixes of cover crops (see Tables 2-8). For the first year of BIOS, we developed several winter-annual cover crop mixes that reflect differing requirements. For example, where tall-statured cover crops can be tolerated in orchard middles, the "Rich Mix" is recommended, because of its great diversity of grasses and legumes, and its high production of organic matter and nitrogen. Where resident annual grasses are already abundant, the "Grassless Rich Mix" may be more appropriate. Where shorter-statured cover crops are required in the middles, the "Low-Grow Mix" is an alternative. 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". For drip-irrigated orchards, the options are limited to drought-tolerant varieties, such as those contained in the "Drip Mix". 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.

All the BIOS cover crop mixes are sown in autumn, grow vegetatively through late March, flower in April and May, and have mature seed by mid-June. The following 4 figures (Figures 1-4) illustrate the complexes of plants contained in typical BIOS mixes, during February and April.

Figure 1. Winter-annual cover crop stand in February.

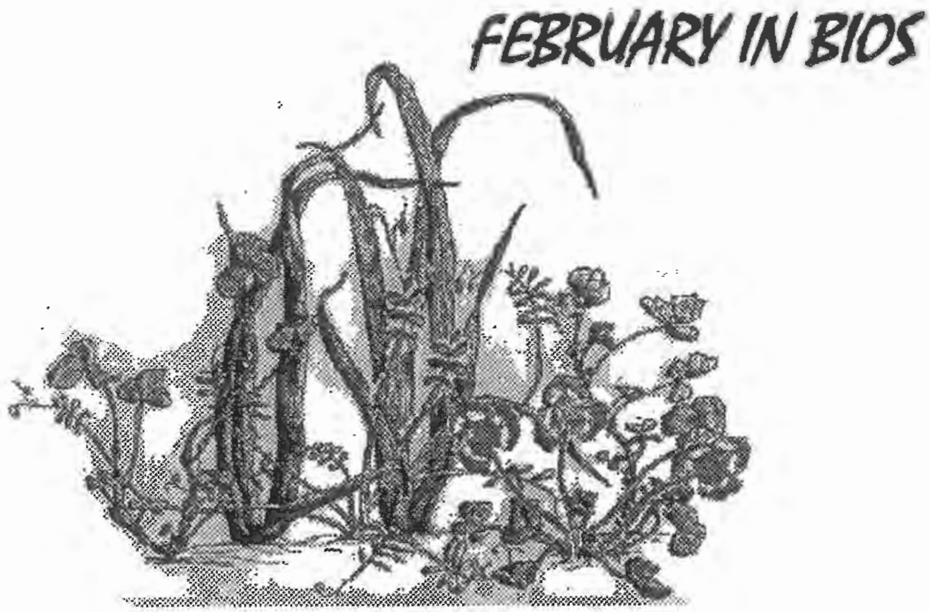


Figure 2. Winter-annual cover crop stand in February, with species names included.

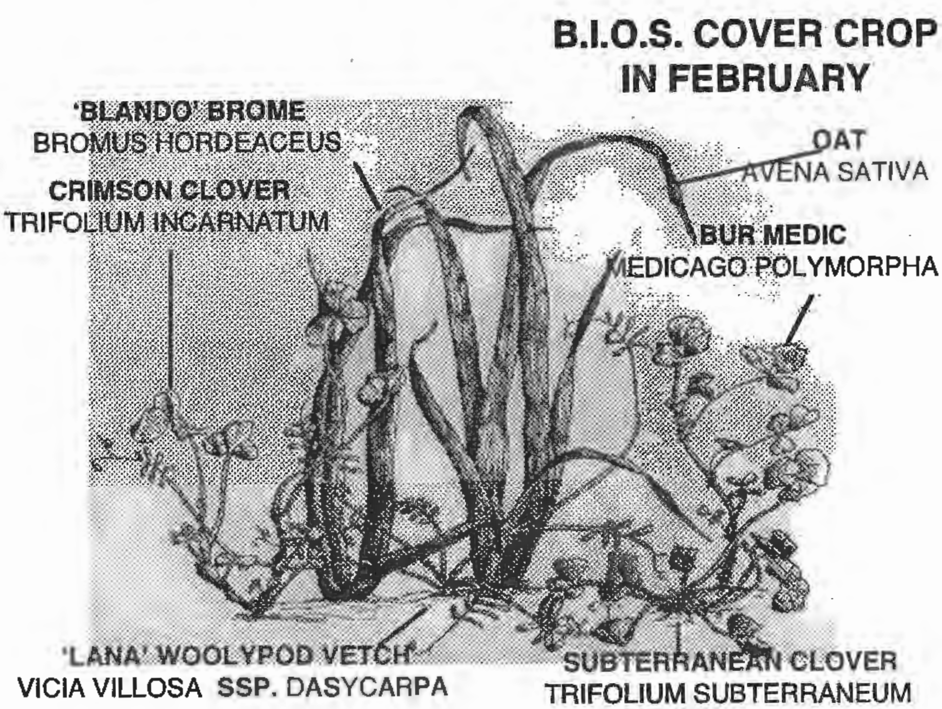


Figure 3. Winter-annual cover crop stand in April.

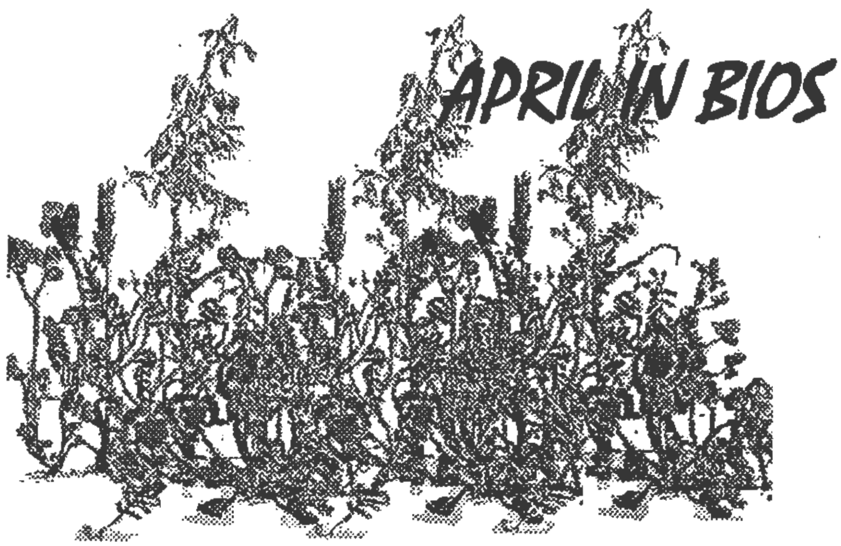
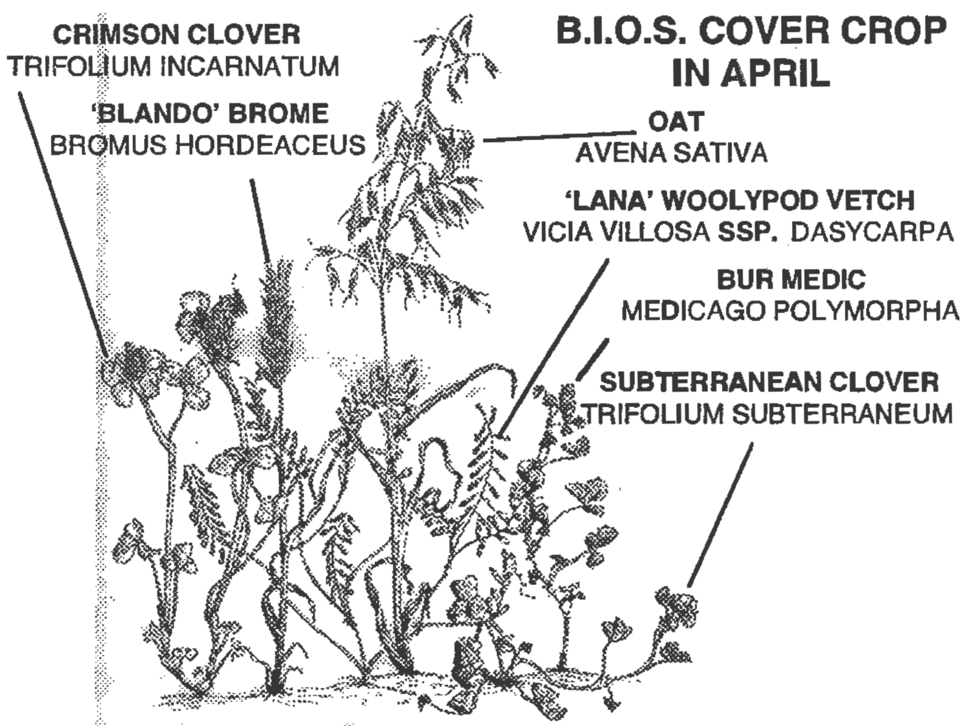


Figure 4. Winter-annual cover crop stand in April, with species names included.



The Art of Mowing

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) Reduce weed competition with cover crops (6″ mowing in February or early March).

(3) Postpone maturation of cover crops (high mowing in April or early May).

(4) Rejuvenate cover crops (postpone their maturation) and increase overall biomass production. This can be accomplished by high mowing followed by irrigation.

(5) Provide food for earthworms and other decomposers and thereby "jump start" the release of N.

(6) Provide mulch for beneficial arthropod habitat, weed control, and to reduce evaporative loss of soil moisture.

(7) Provide "habitat edges" for beneficial arthropods, at the interface between mowed and unmowed cover crops.

(8) Provide channels and otherwise accommodate flood irrigation.

(9) Kill cover crops (close mowing in late April-June).

(10) Allow warm-season resident vegetation to emerge through cool-season cover crops.

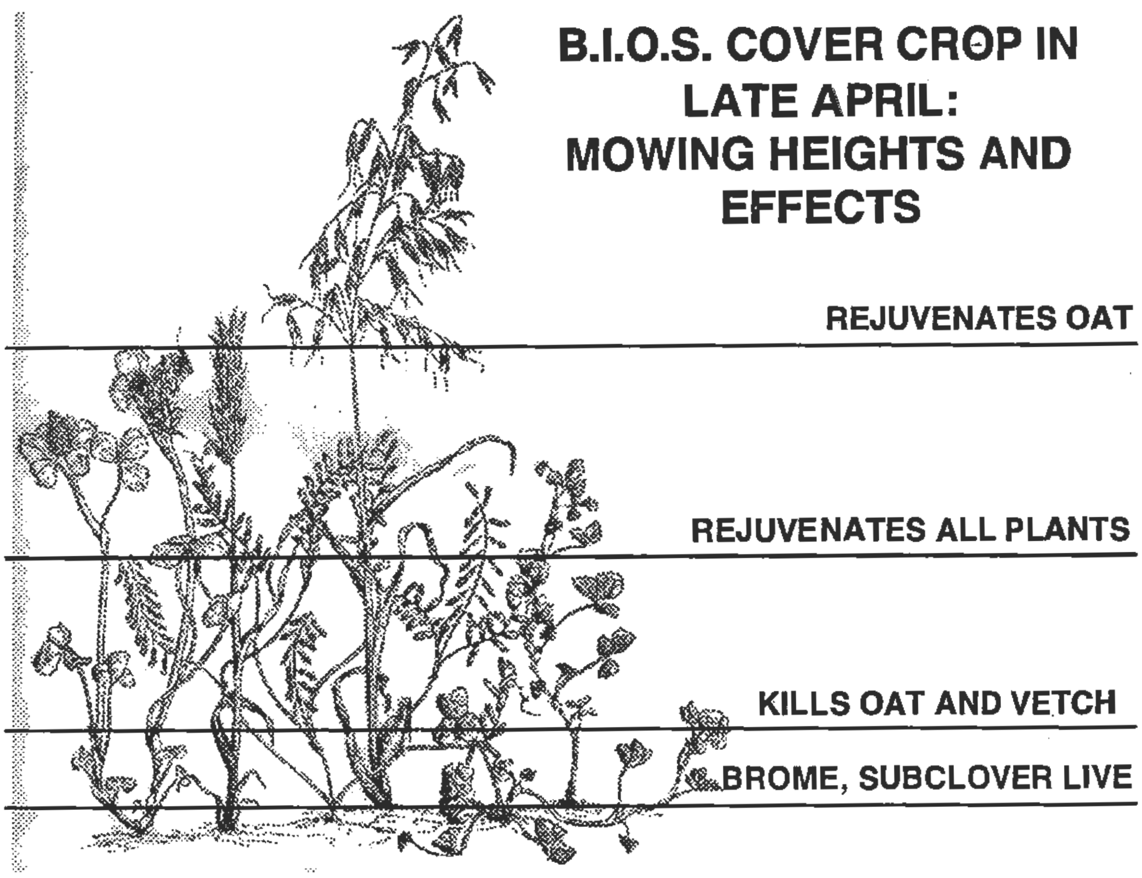
(11) Force beneficial arthropods to move into trees by reducing the amount of understory habitat.

(12) Prepare the orchard floor for harvest.

As suggested above, depending on timing and height, mowing can have varied effects on plants. Therefore, mowing technique must be determined carefully. What we term *biological height of the plants* must be considered in determining the appropriate height of the mowing. This has to do with the heights at which the various plant structures (flowers, foliage, and reproductive or vegetative buds) are presented. The patterns of presentation vary among plant species and with the stage of development of a given species. When mowing is intended to liberate a cover crop from competition by taller weeds, mower height should be set above that of the cover crop. When the object is to rejuvenate a cover crop, mowing should remove the flowers of the cover crop, but preserve the vegetative buds (growth points or meristems), some of which are usually located lower on the plant. If the object is to open up the canopy of a cover crop, mower height should adjusted to remove canopy foliage, but preserve some vegetative buds. If the aim is to kill and annual cover crop, close mowing at full flower is used, to remove all vegetative buds.

If annual clovers (e.g., crimson or subterranean 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. In mid-spring, close mowing may kill annual cover crops that are in full flower. As mentioned above, 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. Most forage legumes produce the maximum amount of biomass and nitrogen when managed with multiple high mowings prior to flowering (see Duke, 1983). However, it is important to note that even high mowing will postpone flowering and the subsequent maturation of cover crop seed. The following figure shows how different mowing heights can have profoundly different effects on various plants in a typical BIOS cover crop.

Figure 5. Winter-annual cover crop stand in April, with mowing heights and probable effects on various species.



To ensure self-regeneration of cover crop stands, we suggest leaving "remnant bands" of cover crops unmowed (a minimum of about 30% of the seeded understory acreage). This permits prompt production of mature seed that may be sufficient to reseed the entire understory. We suggest that April mowing be fairly high (at least 10"). Alternate row mowing is used by many growers in attempts to retain habitat for insects and other arthropods. The usefulness of this approach in walnut orchards has not been tested in formal scientific studies.

Containing The Cover Crop

Vetches present some challenges in sprinkler-irrigated orchards, because they can climb and block emitters. Under some conditions, excessive growth at tree bases may predispose for problems with phytophthora crown and root rots. Purple vetch and 'Lana' woollypod vetch are very vigorous and are especially prone to cause these problems. They are also relatively resistant to glyphosate (Roundup®). One solution to this problem is to use glyphosate at a higher rate (up to 2 quarts active ingredient/acre) and with supplemental surfactant (e.g., 1-2 quarts/acre of X-100). This approach has worked well against hairy vetch in southern Georgia (Sharad C. Phatak, personal communication). Alternatively, growers can make use of common vetch the hybrid 'Cahaba White' vetch (*Vicia sativa* X *V. cordata*), which is less vigorous and less prone to climb, and is susceptible to glyphosate at the normal rate of 1 pint active ingredient/acre. The vetches can thus be controlled using either strip or spot spraying. An alternative to herbicides is to mow closely (e.g., with a weed-eater around emitters or tree bases) during late February or early March, to favor the lower-growing and non-vining clovers and medics. Mechanical control can otherwise be obtained using a weed-eater or a rake. If vetches are rooted in the middles but extend into the tree rows, the invasive vines can be cut using tractor-drawn colter discs.

Methods

a. Disk to prepare good seedbed.

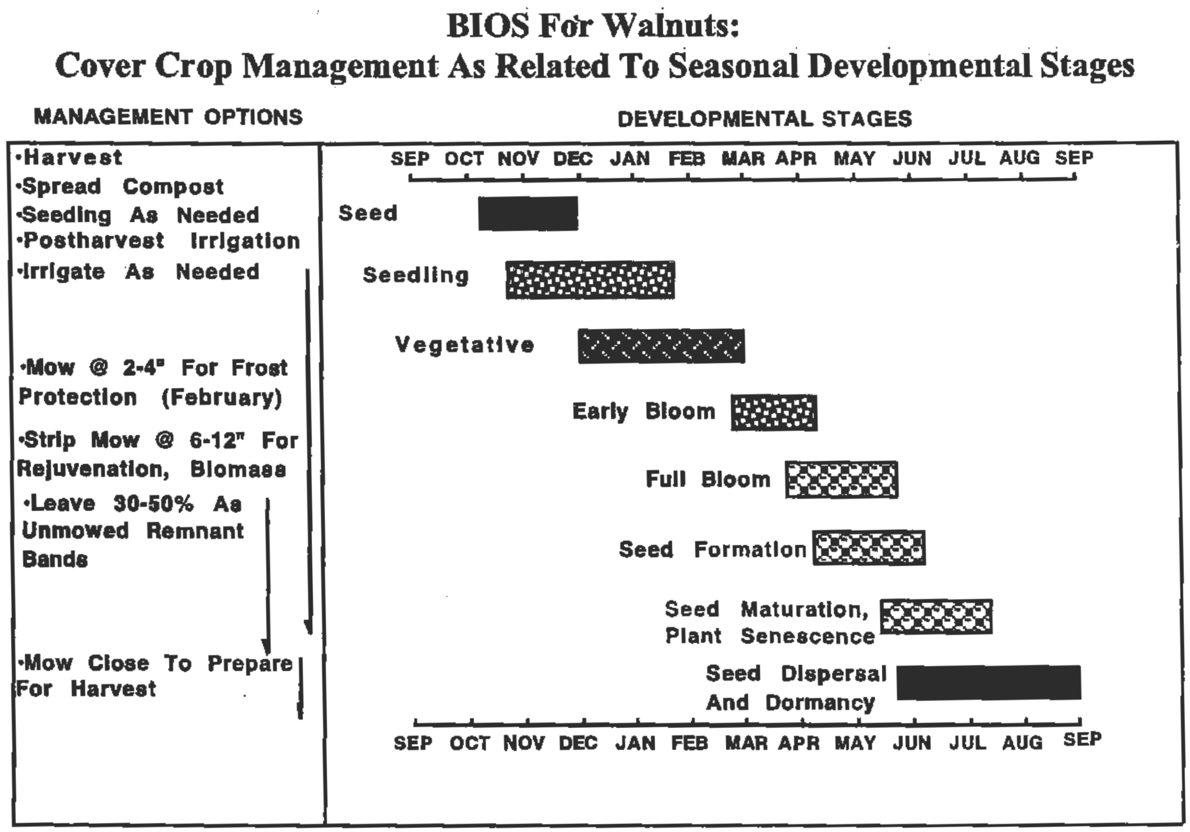
b. Inoculate and broadcast seed.

c. Incorporate seed using a drag. 1/2″ depth is a good compromise depth if there is a mixture of large- and small-seeded species.

d. Sprinkler irrigate with 1.5″ water.

General cover crop management in walnut is summarized in the following figure.

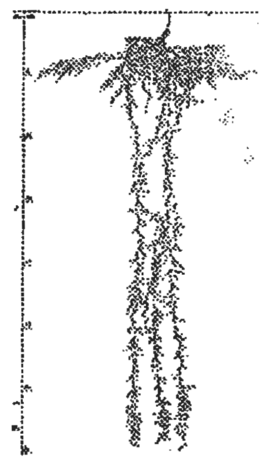
Figure 6. Developmental stages and management scheme for winter-annual cover crops in English walnut orchard.



Nitrogen Dynamics in Cover-Cropped Orchards

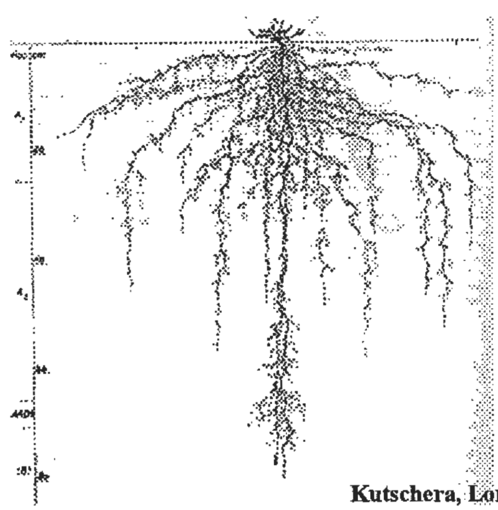
Different plants have different potential functions in BIOS. For example, legumes such as clovers, medics, and vetches have symbiotic bacteria in their roots that allow them to "fix" atmospheric nitrogen (See Appendix on legume inoculation). Typically, about 3/4 to 4/5 of the total legume nitrogen is contained in the above-ground portions. The rest is contained in legume root systems, which are usually dominated by a single taproot or a few strong vertical roots. Legume root systems have also been shown to release nitrogen into the soil. In some cases, the living root systems of winter-annual legumes have been shown to shed 15-20 kg/ha of nitrogen during the growing season. This nitrogen may be taken up by nearby grasses or other plants. Cross-sections of root systems for two commonly used BIOS cover crops are depicted below in the following two figures.

Figure 7. Root system of woollypod vetch (*Vicia villosa* ssp. *dasycarpa*): About 70 cm (about 27.6″) rooting depth.



Kutschera, Lore. 1960.
Wurzelatlas Mitteleuropäischer Ackerunkräuter und Kulturpflanzen.
DLG-Verlags-GMBH, Frankfurt Am Main, Germany.

Figure 8. Root system of common vetch (*Vicia sativa*): About 80 cm (about 31.5″) rooting depth.



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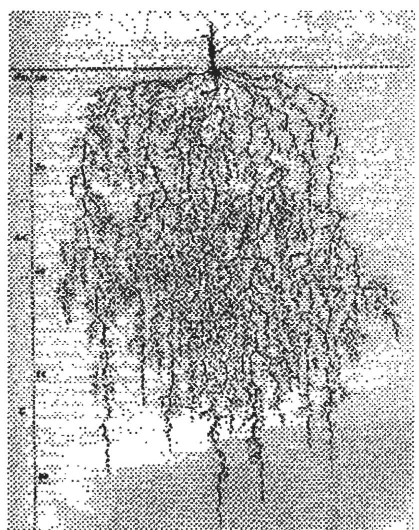
DLG-Verlags-GMBH, Frankfurt Am Main, Germany.

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 lb of nitrogen per acre or more. Other vetches, like common, hairy, or purple vetches; clovers; and medics typically contain less nitrogen than does woollypod vetch.

Grasses do not usually fix atmospheric nitrogen, but their fibrous roots systems (like the wild oat root system shown here) are good at taking up nitrate and preventing it from leaching through the soil.

Figure 9. Root system of wild oat (*Avena sativa*): About 90 cm (about 35.4") rooting depth.



Kutschera, Lore. 1960.
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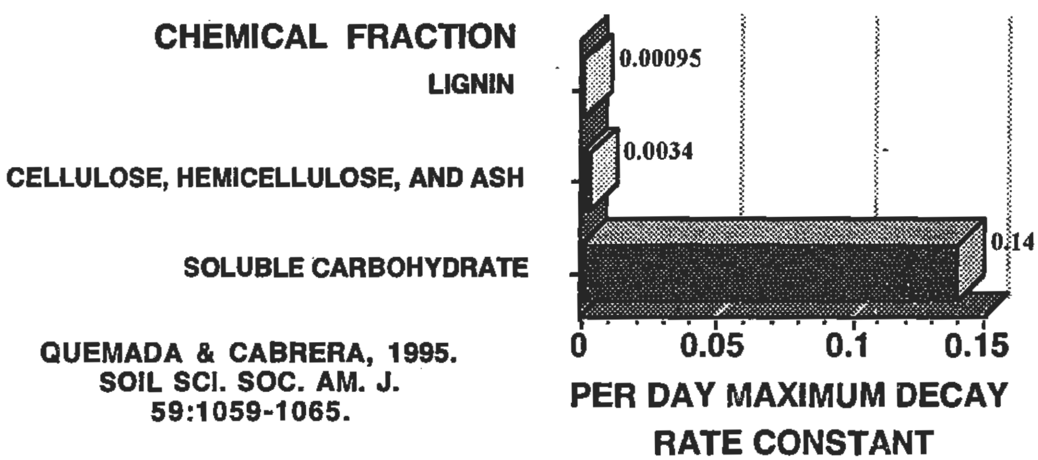
DLG-Verlags-GMBH, Frankfurt Am Main, Germany.

For example, in a field-crop environment in France, a catch crop of Italian (annual) ryegrass reduced N leaching from 124 kg N/ha to 40 kg N/ha. Different cover crops have differing chemical compositions and carbon:nitrogen ratios, as shown by Quemada and Cabrera (1995). In general, plant residues with higher carbon:nitrogen ratios decompose less rapidly than those with lower ratios. In addition, different types of carbon-rich chemicals break down at different rates, as shown in this figure based on data from Quemada and Cabrera (1995).

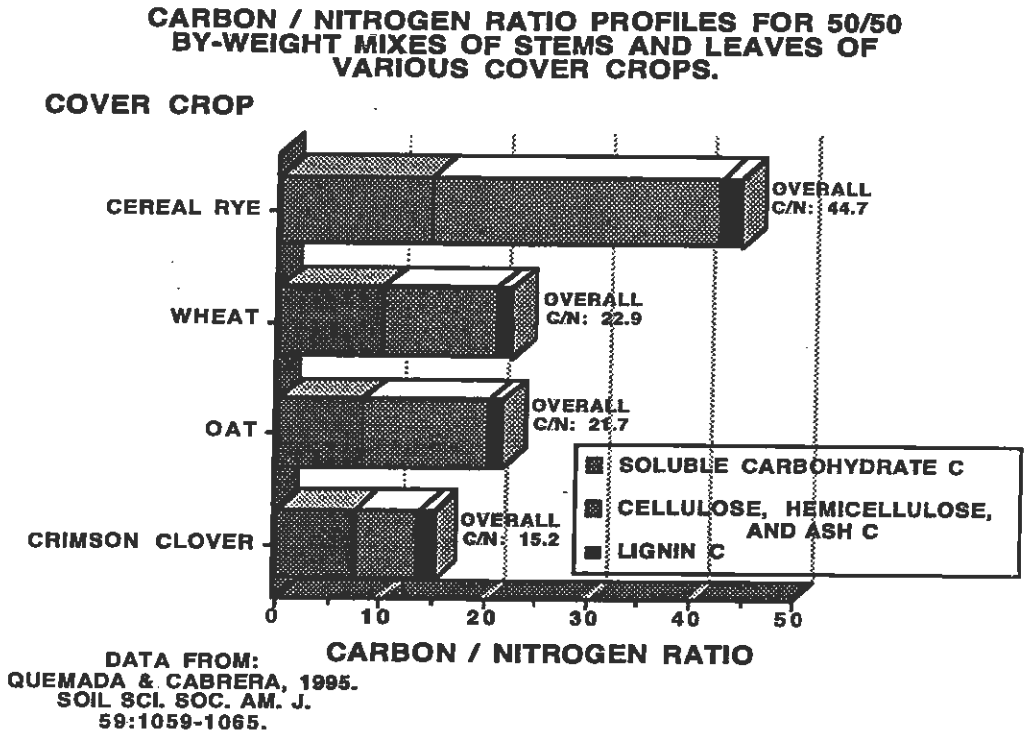
Figure 10.

PER DAY MAXIMUM DECAY RATE CONSTANTS OBSERVED FOR VARIOUS CHEMICAL FRACTIONS OF COVER CROPS.



As shown in the figure, in no-till systems (like most BIOS orchards) the proportions of carbon released per day for different plant chemicals range from about 0.14 for total soluble carbohydrate, to about 0.003 for cellulose, hemicellulose, and ash, to as little as 0.00095 for lignin. This means that soluble carbohydrates (sugars) break down about 41 times faster than cellulose, hemicellulose, and ash, and about 147 times faster than lignin. Therefore, woodier materials with much cellulose, hemicellulose, and lignin (e.g., cereal rye) are much slower to break down and disappear than litter produced by crimson clover or even oat. Observations of many BIOS growers confirm this, and this has led to cereal rye being excluded from most of the BIOS cover crop mixes that are used in nut orchards.

Figure 11.



Residues of mature grass usually do not break down very rapidly, but when they finally decompose, the lignin is in part converted to the humic and fulvic acids that are important in maintaining soil fertility. Fiddleneck, field mustard, black mustard, and wild radish are good at taking up soil nitrate; their residues decompose quicker than do residues of mature grass.

In a replicated trial conducted in Craig McNamara's flood-irrigated hedgerow (Putah Creek) orchard, Chuck Ingels, Bob Bugg, and Craig estimated above-ground biomass production (Fig. 12), % N content (Fig. 13), and kg/ha nitrogen contents (per seeded acre) (Fig. 14), for the Low-Grow Mix and the Rich Mix. These cover crops, seeded in November, showed vigorous growth by mid-April, when the biomass harvests were made.

Figure 12.

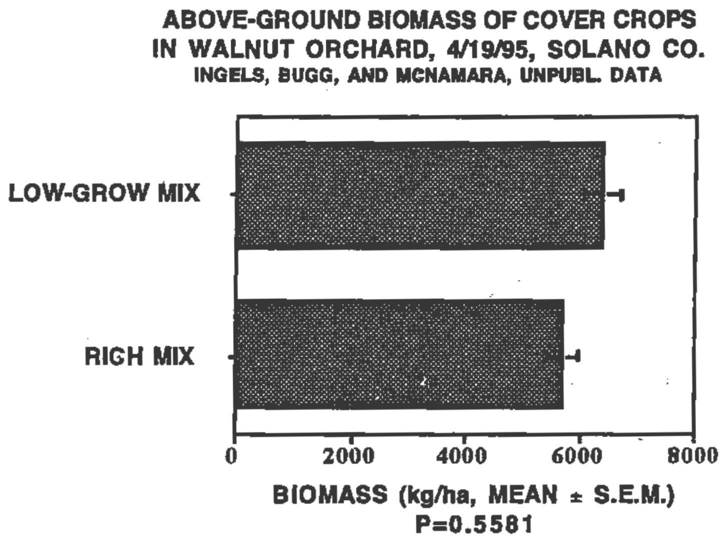


Figure 13.

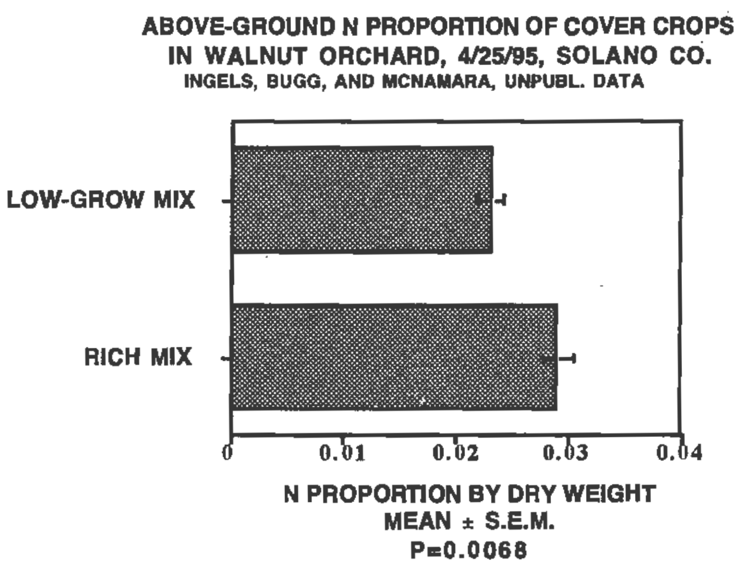
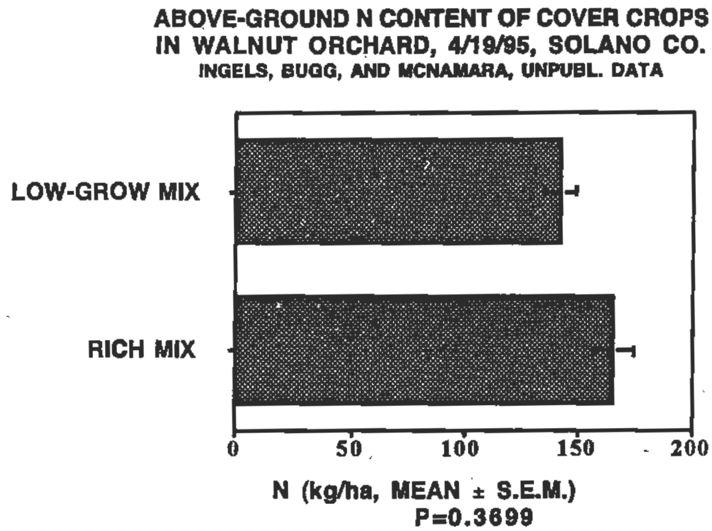


Figure 14.



Additional measurements in other BIOS orchards indicated mean N contents of from 88 to 166 kg N / ha, with some individual measurements exceeding 200 kg N /ha. These numbers are based on one-time "snapshots" of cover crops in mid-Spring. With multiple mowings and regrowth, cover crop biomass and nitrogen production are likely to be substantially higher, but figures are not available for these management approaches.

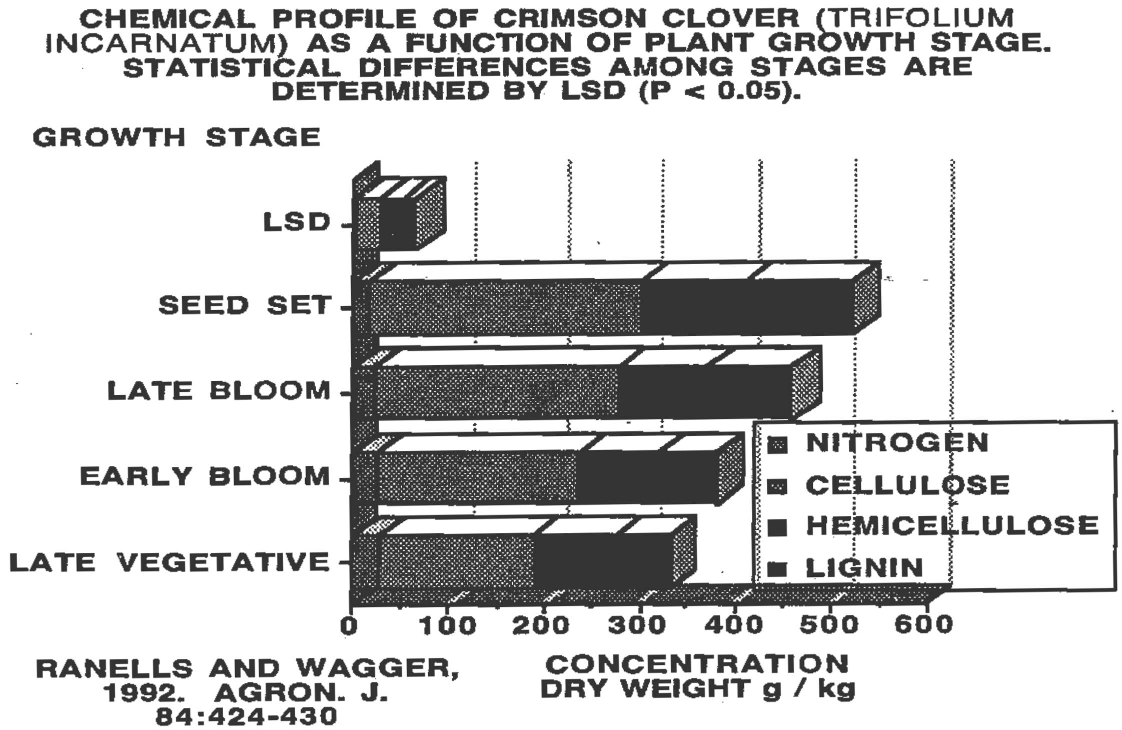
There is controversy as to whether no-till management of cover crops will lead to sufficient soil nitrogen for walnut trees. This is an important issue, because in California, orchard cover crops are merely mowed, and residues are not incorporated. The issue partly depends on what percentage of cover-crop N volatilizes as ammonia (NH_3); that N is presumed lost to the orchard trees. California studies are lacking; therefore, growers and agricultural consultants should consider scientific literature from other regions. In Terman's (1979) review of ammonia-volatilization issues, he noted that crop utilization of N from surface-applied materials ranges from 30-70% and may average about 50%. Losses of NH_3 increase with increase in the intensity of drying conditions (higher temperatures, more air movement, and lower humidity), with higher soil pH, with coarse-textured soils of low cation exchange capacity, and with lower initial soil moisture content. Losses are very low if various N sources are incorporated into the soil or are moved at once into the soil by rain or irrigation. In the humid south, little N appears to be lost in this way, when leguminous cover crops are managed without tillage. In Georgia, on gravelly clay loam and sandy clay loam soils, McVay et al. (1989) conducted a trial of no-till corn and sorghum production under various cover-cropping regimes. Hairy vetch and crimson clover grown as winter cover crops respectively replaced on the average 123 and 99 kg/ha of fertilizer N. The corresponding above-ground N contents of cover-crop herbage were 128 and 108 kg N/ha. These results suggest efficient cycling of N in a no-till system, with minimal losses due to volatilization of NH_3.

By contrast, in the Northeast and the Midwest, cyclic wetting and drying may lead to the loss of from 1/3 to 1/2 of the N contained in surface-managed leguminous residues, regardless of the pH of the soil (Sarrantonio and Scott, 1988). Even if field conditions do not lead to substantial loss of NH_3, N availability to the target crop may be delayed in no-till systems, as suggested by Lemon et al. (1990) for berseem clover preceding grain sorghum in Burleson County, Texas.

Dr. William L. Hargrove of the University of Georgia has extensive experience in managing no-till cool-season annual legumes and in assessing their N contributions to warm-season annual field crops; he is also an authority on NH_3 volatilization. In discussions with R.L. Bugg, Hargrove (personal communication, 1994) stated that NH_3 volatilization should be minimal and N from cover-crop residues should become available to trees if understory conditions remain relatively moist during the principal period that the clippings are decomposing. Shading and irrigation, of course, would aid in maintaining the desired moist conditions. Hargrove further indicated that staggered mowing patterns, such as those recommended in BIOS, will further reduce volatilization by reducing the concentration of NH_3 during any one period of decomposition. Rainfall in Georgia averages about 4 inches per month throughout the year; this corresponds well with the amounts of water applied to sprinkler-irrigated almond orchards (36 inches over 9 months), and is less than the amounts applied to walnut orchards (48 inches over 7-8 months). Clearly, in sprinkler- or flood-irrigated Californian orchards, the understory microclimate is far from Mediterranean.

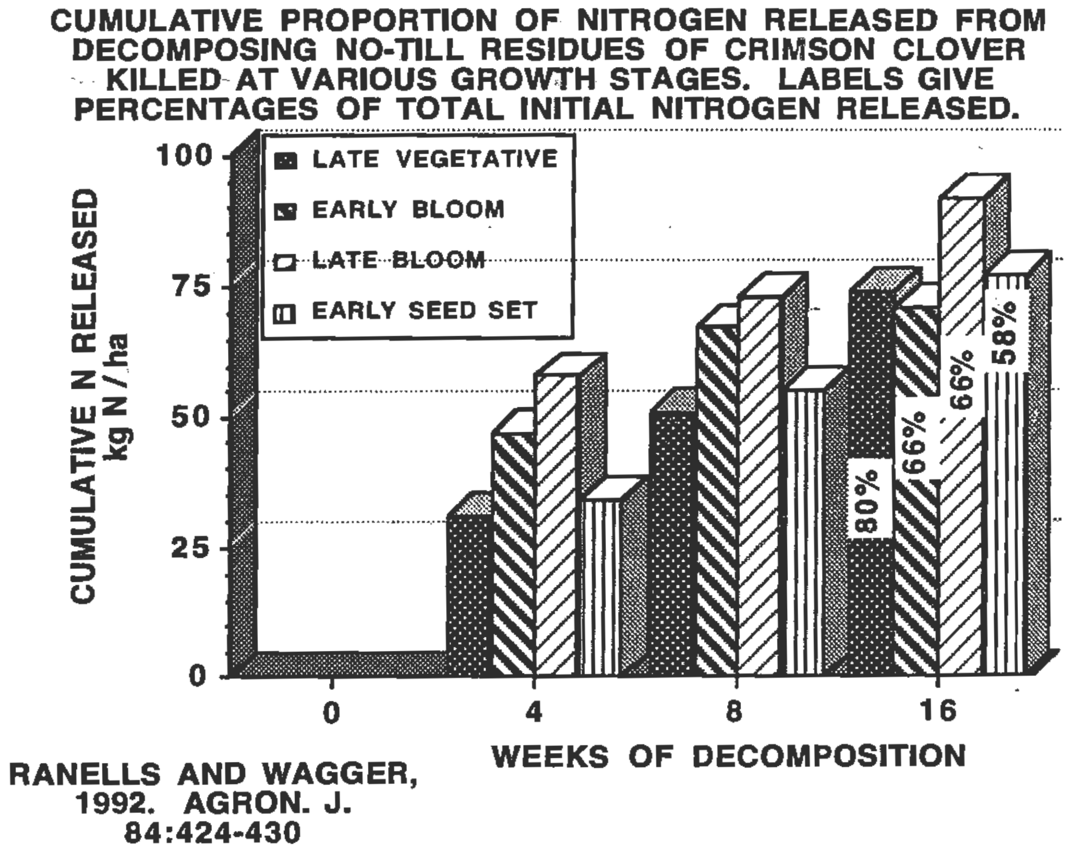
Many BIOS growers mow their cover crops several times during the winter and spring, which may postpone maturation and lead to higher total biomass and nitrogen production, as mentioned earlier. As shown for crimson clover by Ranells and Wagger (1992), the stage of maturity at which a cover crop is killed affects the speed of breakdown and liberation of the nitrogen. Nitrogen is more readily released from young, succulent, vegetative tissues than from older, plants that have become more woody and have a lower by-weight concentration of nitrogen.

Figure 15.


CHEMICAL PROFILE OF CRIMSON CLOVER (TRIFOLIUM INCARNATUM) AS A FUNCTION OF PLANT GROWTH STAGE. STATISTICAL DIFFERENCES AMONG STAGES ARE DETERMINED BY LSD (P < 0.05).
GROWTH STAGE
LSD
SEED SET
LATE BLOOM
EARLY BLOOM
LATE VEGETATIVE
NITROGEN
CELLULOSE
HEMICELLULOSE
LIGNIN
0
100
200
300
400
500
600
RANELLS AND WAGGER, 1992. AGRON. J. 84:424-430
CONCENTRATION DRY WEIGHT g / kg

However, total nitrogen released 16 weeks after killing was greatest for crimson clover killed at late bloom stage, because biomass is higher than with the stands at late vegetative and early bloom stages.

Figure 16.



Numerous Californian farmers manage leguminous cover crops without tillage in sprinkler-irrigated orchards. These growers include Ray Eck and Cynthia Lashbrook of Merced County and Russell Lester and Craig McNamara of Solano County, all members of BIOS management teams. These farmers report that they have observed no N deficiencies in their orchards after 1-6 years under no-till management. Ray Eck and Russell Lester have suggested that the relatively frequent waterings coupled with dense shade on the orchard floor promotes a moist soil surface and rapid breakdown of leguminous residues. Moreover, these growers point to the high incidence of decomposers (fungi, crickets, earthworms, pillbugs, sowbugs, earwigs) in their orchards, and the abundant growth of surface feeder roots. All these conditions would favor rapid and efficient cycling of legume-derived N.

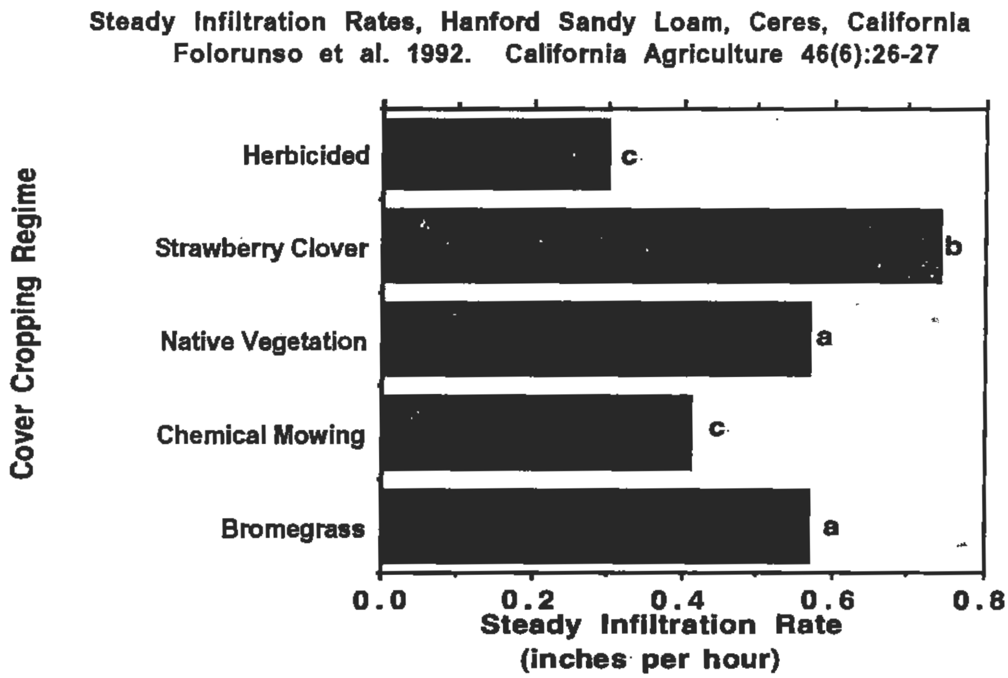
Critical studies are clearly needed to determine the availability of N in cover-cropped walnut orchards managed with little or no tillage, and under various irrigation regimes.

Cover Crops and Water Use

Under some conditions, improved infiltration caused by cover cropping may lessen the need for irrigation. 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. Use of mown cover crop residue as mulch can help retain soil moisture and encourage earthworms.

Cover cropping can lead to greatly improved water penetration on sandy soils, based on studies by Folorunso et al. (1992) in the San Joaquin Valley (Fig. 17).

Figure 17.



Cereals may lead to improved infiltration on heavier soil in Yolo County, as was shown by W.A. Williams of the U.C. Davis Department of Agronomy and Range Science (Williams et al., 1960; Williams, 1966). Williams (1966) found an increase in infiltration rate of irrigation water was inversely related to the nitrogen concentrations of nonleguminous green manures at the time of incorporation by disking. Barley (*Hordeum vulgare* cv 'Atlas 40', cereal rye (*Secale cereale* cv 'Svalof Fourex'), annual ryegrass (*Lolium multiflorum*), and soft chess (*Bromus mollis* cv 'Blando') significantly improved infiltration rate in a loamy, well-drained soil, but black mustard (*Brassica nigra*) did not (Fig. 18, 19).

Figure 18.

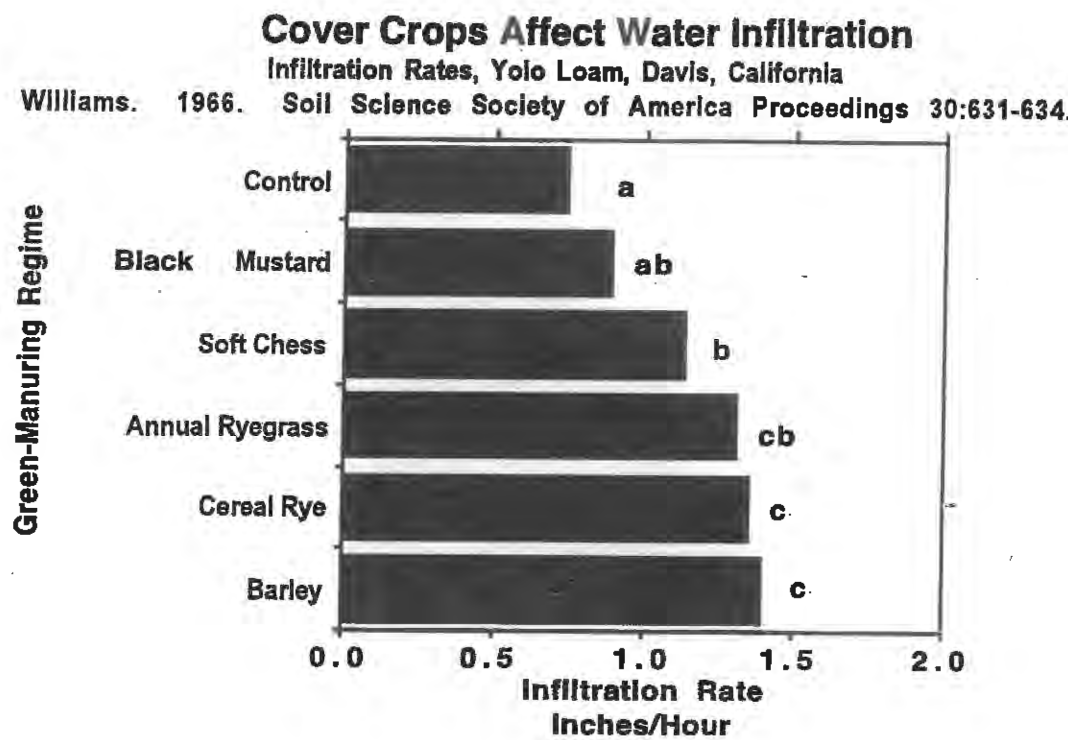
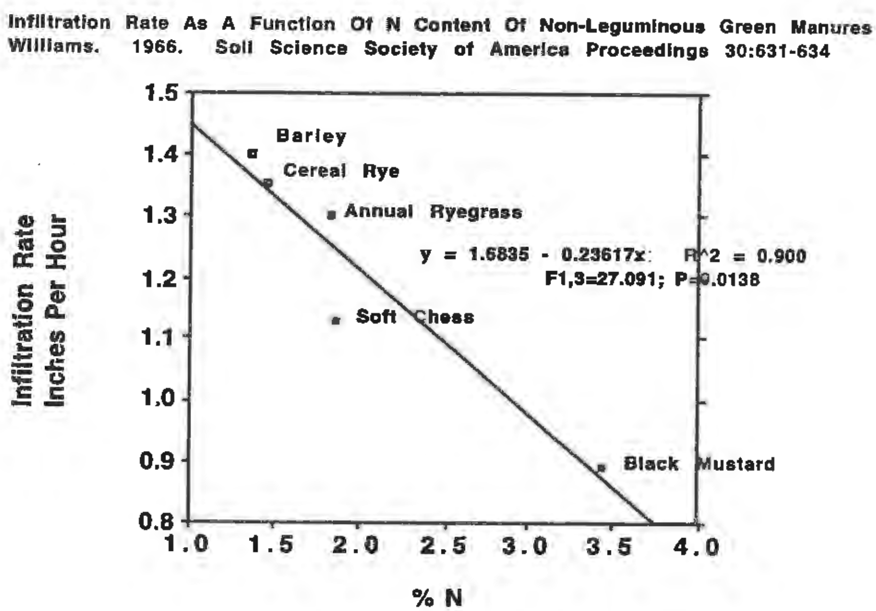


Figure 19



Research in almond orchards by Prichard et al. (1989) suggests that an early-maturing annual grass (soft chess, *Bromus mollis,* also known as 'Blando' brome) managed by mowing results in about the same annual water use as a weed-free (herbicided) understory. This corresponds well with reports by orchardists who use winter-annual cover crops in orchards of walnut (Russell Lester) and almond (Ray Eck and Cynthia Lashbrook). These orchardists report no net increase in irrigation requirements since cover cropping was begun.

Cover cropping may affect soil structure by supporting the growth of soil microbes. Some of these micoorganisms produce polysaccharides that in turn promote the formation of water-stable aggregates, particles of soil resistant to erosion by water. This phenomenon leads to improved soil structure and increased rates of water penetration. In a study by Roberson et al. (1991), various understory-management regimes were applied to experimental plots in a flood-irrigated prune orchard in Gridley, Butte County, California, in order to determine various effects on the loam soil. Understory management systems were as follows:

(1) permanent cover with perennial ryegrass, *Lolium perenne;*

(2) annual cover occasionally mowed, using the fall-sown cereals barley, *Hordeum vulgare,* or wheat, *Triticum aestivum;*

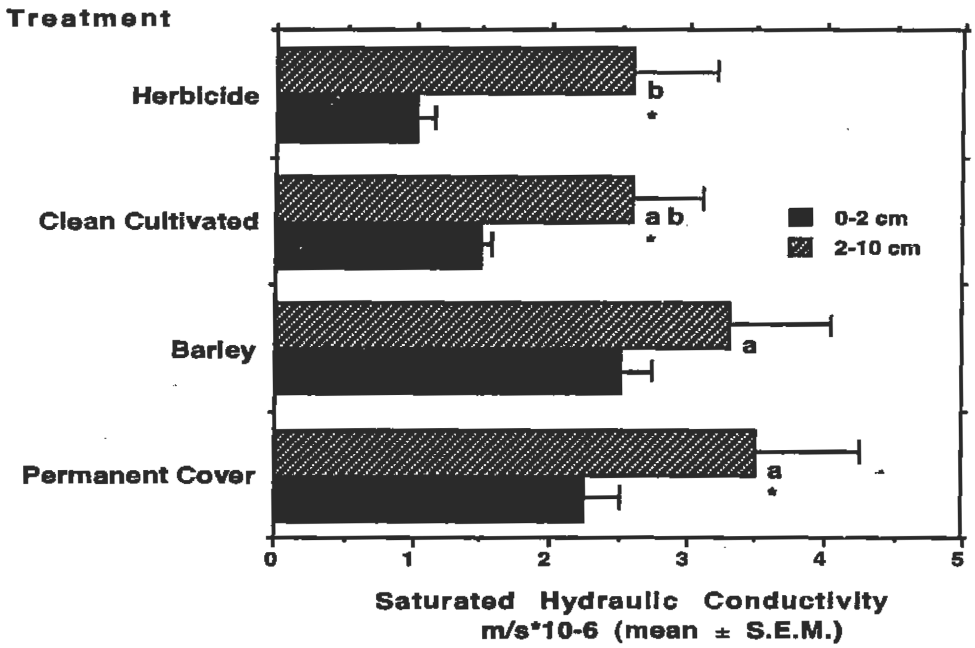
(3) fall-sown barley or wheat killed in May using glyphosate (this substantially decreased the biomass provided by the cereals);

(4) clean-cultivation using occasional disking to break surface crusts and reduce weeds.

The higher amounts of carbon available to microbes in the permanent cover and mowed barley treatments appear to translate into improved soil structure and water infiltration.

Figure 20.

Saturated hydraulic conductivity in prune orchard understory, Butte County, California, 1988 (Roberson et al., 1991).



This occurred through short-term increase in the heavy-fraction carbohydrates, but was not reflected in statistically higher concentrations of total organic carbon or microbial biomass carbon. The loam soil in this study had low organic matter, little structure, and was very prone to crusting. Thus, it was more susceptible than some other soils to rapid improvement through additions of organic matter. Also, in other soil types, clay, humified organic matter, or iron oxides may be more important in the aggregation process.

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, 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.

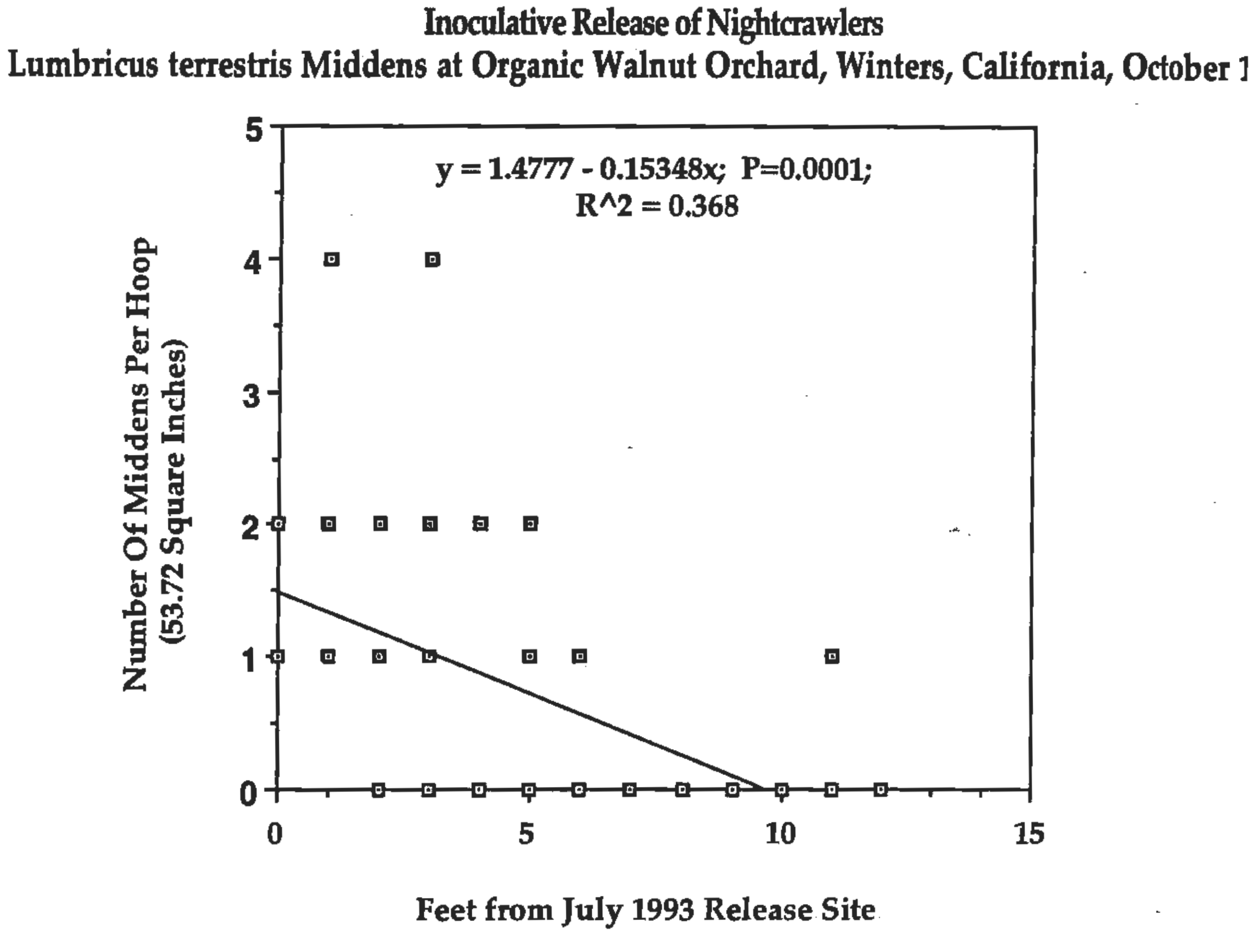
Earthworms are among the most obvious decomposers, and they are abundant in several orchards that are now under BIOS management or that are now being converted. Other decomposers abundant in walnut BIOS orchards of Solano and Yolo Counties include field cricket, European earwig, pillbugs and sowbugs (both of which are crustaceans), and various types of slugs (which are gastropod molluscs).

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. 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 burrow horizontally; (2) endogeic earthworms feed and live deeper in the soil, and burrow horizontally; and (3) anecic earthworms pull plant debris underground, and burrow vertically. Some earthworms may change feeding strategy based on field conditions. For example, some species that are mainly endogeic may feed at the soil surface. Earthworms found in walnut BIOS orchards are mainly in the family Lumbricidae and include the two endogeic species *Allolobophora chlorotica* (which is pale green, slow-moving, and appears to tie itself in knots) and *Apporrectodea trapezoides*. (which is usually pale pink), the epigeic species *Lumbricus rubellus* (dark red, fast moving, with an acrid yellow excretion that it discharges when handled, commonly called "the pasture earthworm"). The nightcrawler *Lumbricus terrestris* is usually lacking initially from orchards, but may become established on loam to clay soils in orchards that have sprinkler or flood irrigation. This species may be $11^{3/4}$" long, is fast-moving when excited, and is dark on the head, with a pale, flattenable tail, fast moving, termed. The compost earthworm, *Eisenia fetida*, is commonly sold as fish bait. It is dark red and, although smaller, it may be mistaken for the pasture earthworm. It will not survive orchard conditions, and therefore should not be released. *Amynthas diffringens* is in the family Megascolecidae. It originated in southern Asia, e.g., Myanmar (formerly Burma), and is common in California gardens and sometimes in orchards. This species has a type of excretory system that renders it more tolerant of dry conditions than are the Lumbricidae mentioned earlier. *Amynthas diffringens* is up to about 8" long, is extremely fast moving, and, based on field and laboratory observations, appears to show a combination of epigeic and anecic behaviors. Pigmentation varies from dark tan on the head to bright or pale pink on the tail. Specimens appear to become paler when held in captivity and not exposed to sunlight. It is not clear whether this earthworm can be established within orchards where it was originally lacking. Pilot releases have been made in Russell Lester's home orchard.

Castings (earthworm droppings extruded onto the soil surface) are a good indicator of some types of earthworm (e.g., *Aporrectodea trapezoides*) activity. These can be observed best immediately after irrigation. *Lumbricus terrestris* often forms distinctive "middens". These are turret- or cairn-like structures that overlay the deep vertical burrows. Leaves, grasses, etc., that have been partly dragged underground by the worms my protrude from the middens. Options for increasing earthworms include inoculative release of species that are absent, and tailoring cover-cropping, mowing, tillage, and chemical regimes.

Lumbricus terrestris is often lacking from conventional orchards, apparently due to its susceptibility to tillage and various agrichemicals. Moreover, in the Central Valley, suitable fieldside habitat are lacking, so the nightcrawlers cannot recolonize orchards. Despite these problems, nightcrawlers can be released and will establish in walnut orchards with loam to clay soil and in which sprinkler or flood irrigation is used. In Russell Lester's home orchard, Bob Bugg released nighcrawlers and observed their establishment and spread. As shown in Figure 1, nightcrawler colonies appeared to expand at a rate of about 3 m (about 10 feet) per year.

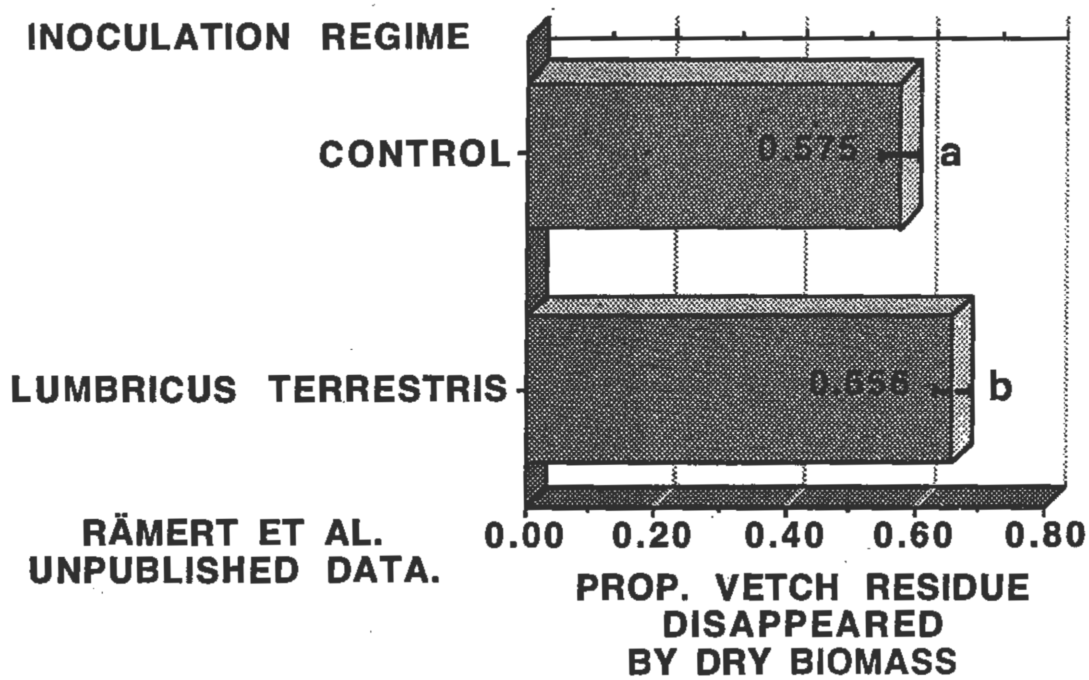
Figure 21.



Results from studies in Europe suggest that *Lumbricus terrestris* colonies can spread up to about 5 m (about 16 feet) per year. The species drags fallen walnut leaves and cover crop mowings underground. Studies in Davis by the visiting Swedish researcher Birgitta Rämert and coworkers showed that inoculative release of nightcrawler during the previous year led to about an 8% increase in vetch incorporation in a no-till orchard, over a 6-week period (Fig. 22).

Figure 22.

DISAPPEARANCE OF WOOLLYPOD VETCH RESIDUE FROM PLOTS IN AN ORGANIC WALNUT ORCHARD, WINTERS, YOLO CO., CALIFORNIA, 1996.
P = 0.0305.



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UNPUBLISHED DATA.

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Table 1. 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 taken from values in the U.C. S.A.R.E.P. cover crop data base, if these are available.

Cover Crop Name	Height, cm, Mean ± S.E.M.,	Above-ground biomass, dry, Mg/ha, Mean ± S.E.M.	Above-ground nitrogen content, kg/ha	Remarks
Burr Medic ('Circle Valley')	34.93±5.43	8.35±1.84	62-140	Volunteers in Merced orchards. Matures in late April. Tolerates alkalinity. Acid-tolerant rhizobia are required on low-pH soils.
Crimson Clover ('Flame')	48.90±15.77	8.46±1.48	49-92	Matures in mid-May. Requires winter mowing to encourage. Tolerates sandy soils and low pH; does not tolerate waterlogged soils.

Rose Clover ('Hykon')	43.18±3.28	6.15±1.67	50-100	Matures in mid-May. Requires winter mowing to encourage
'Koala' Subclover	45.72±2.93	9.66±1.61	202	Tallest subclover, matures in mid-May; tolerates alkaline soils. Requires winter mowing to encourage.
'Mt. Barker' Subclover	36.83±2.64	7.63±0.99	251	This late-maturing variety ripens seed in June. Requires winter mowing to encourage.
'Seaton Park' Subclover	37.47±2.40	6.81±0.38	-	Late-maturing variety. Requires winter mowing to encourage.
'Dalkeith' Subclover	31.75±1.27	5.13±1.84	-	Early-maturing, low statured and low biomass. Requires winter mowing to encourage.

'Trikkala' Subclover	43.82±1.60	8.28±1.37	224	Tolerates flooding and heavy soils.. Mid-May maturation..
Common Vetch	54.61±3.02	8.91±0.95	134	Matures in late May and early June.. Extrafloral nectaries and cowpea aphid attract beneficial insects..
Purple Vetch	57.15±4.46	10.12±0.54	50-300	Matures in late May and early June.. Tolerates heavy soils..
Woollypod Vetch ('Lana')	67.31±4.21	9.18±0.93	50-250	Matures in mid-May.. Best N-fixer of the self-reseeding winter annual legumes..
Annual Ryegrass	92.08±4.20	8.51±3.26	50-235	Matures in late May to early June.. May compete with almonds for water and N..

Barley ('U.C. 476')	94.62±6.17	12.94±2.64	36-104	Matures in late April. Tolerates drought and salinity, but not waterlogging.
Cereal Rye ('Merced')	148.59±7.59	9.88±1.79	38	Matures in early May. Tolerates waterlogged soils. Residue is lignin-rich and slow to break down.
Foxtail Fescue ('Zorro')	60.33±12.59	7.49±0.87	-	Matures by late April. Tolerates drought and sandy soils. Does not support vetches.
Oat ('California Red')	109.22±3.74	12.53±1.43	12	Matures by mid May. This cv lodges easily. Other cvs ('Ogle,' 'Swan,' 'Cayuse') produce more biomass and support vetches better.

Soft Chess ('Blando')	100.97±2.17	9.45±1.44	-	Matures by late April. Tolerates drought and sandy soils. Does not support vetches.

Table 2. "Rich Mix" for orchard understories. Seed at 65 lb per seeded acre.

Cover Crop	% By Weight In Mixture
'Lana' Woollypod Vetch	30
Common Vetch	20
Purple Vetch	12.5
'U.C. 476' Barley	5
'Ogle' or 'Swan' Oat	5
'Cayuse' Oat	5
'Montezuma' Oat	5
'Flame' Crimson Clover	5
'Santiago' Burr Medic	5
'Koala' Subclover	2.5
'Karridale' Subclover	2.5
'Trikkala' Subclover	2.5

Table 3. "Grassless Rich Mix" for orchard understories. Seed at 65 lb per seeded acre.

Cover Crop	% By Weight In Mixture
'Lana' Woollypod Vetch	35
Common Vetch	25
Purple Vetch	15
'Flame' Crimson Clover	5
'Santiago' Burr Medic	5
'Koala' Subclover	5
'Karridale' Subclover	5
'Trikkala' Subclover	5

Table 4. "Low-Grow Mix" for orchard understories. Seed at 35 lb per seeded acre.

Cover Crop	% By Weight In Mixture
Common Vetch	35
'Santiago' Burr Medic	20
'Flame' Crimson Clover	10
'Hykon' Rose Clover	5
'Koala' Subterranean Clover	10
'Trikkala' Subterranean Clover	10
'Woogenellup' Subterranean Clover	5
'Blando' Brome	5

Table 5. "Microsprinkler Mix" for orchard understories. Seed at 35 lb per seeded acre.

Cover Crop	% By Weight In Mixture
Common Vetch or 'Cahaba White' Vetch	25
'Flame' Crimson Clover	10
'Hykon' Rose Clover	2.5
'Santiago' Burr Medic	35
'Dalkeith' Subterranean clover	5.0
'Koala' Subterranean clover	7.5
'Nungarin' Subterranean Clover	2.5
'Trikkala' Subterranean Clover	7.5
'Woogenellup' Subterranean Clover	2.5
'Blando' Brome	2.5

Table 6. "Drip Mix" for understories of orchards on drip irrigation systems. Seed at 25 lb per seeded acre.

Cover Crop	% By Weight In Mixture
'Hykon' Rose Clover	10
'Flame' Crimson Clover	5
'Santiago' Burr Medic	30
'Dalkeith' Subterranean Clover	15
'Koala' Subterranean Clover	10
'Nungarin' Subterranean Clover	15
'Trikkala' Subterranean Clover	5
'Woogenellup' Subterranean Clover	5
'Blando' Brome	5

Table 7. "Ultra-Dry Mix" for drip-irrigated orchards in dry climates (e.g., west side of lower San Joaquin Valley). Sow at 20 lb per seeded acre.

Cover Crop	% By Weight In Mixture
'Serena' Burr Medic	50
'Santiago' Burr Medic	15
'Hykon' Rose Clover	27.5
'Blando' Brome	5
'Zorro' Fescue	2.5

Table 8. "Annual Insectary Mix" for orchard understories. Seed at 12 lb per seeded acre.

Common Name	Species and Cultivar	Seeding Rate in lb/a	% By Weight In Mixture
White Sweetclover (Annual Form)	*Melilotus alba* cv 'Hubam'	1.2	10
Common Vetch	*Vicia sativa* L.	2	17
Subterranean Clovers 3-4 Varieties	*Trifolium subterraneum*	3	25
Crimson Clover	*Trifolium incarnatum*	2	17
Rye	*Secale cereale*	1	8.3
Triticale	*Triticum aestivum* X *Secale cereale* cv 'Juan'	1	8.3
Barley	*Hordeum vulgare* cv 'U.C. 476'	1	8.3
Sweet Alyssum	*Lobularia maritima*	0.2	1.7
Tidy Tips	*Layia platyglossa*	0.1	0.83
Coriander	*Coriandrum sativum*	0.2	1.7
Celery	*Apium graveolens*	0.1	0.83
Bishop's Weed	*Ammi majus*	0.1	0.83
Toothpick Weed	*Ammi visnaga*	0.1	0.83

Appendix 1:

Inoculating Legume Seed

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 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 "blow it" 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:
Cover Crop Profiles

Annual Fescue (Foxtail Fescue, Rattail Fescue)

Festuca megalura or *Festuca myuros* or *Vulpia myuros* var. *hirsuta*

• 'Zorro' is commercially available cultivar
• Winter-annual grass
• Introduced from Europe; foxtail fescue is naturalized in the western states; rattail fescue is naturalized in much of the U.S.
• About 23" tall.
• Biomass about 6,000-8,000 lb/acre
• N content about 1%
• Needs little water to produce seed
• Managed without tillage
• Flowers March-June
• Prone to lodging
• Grown as an annual cover crop in low-fertility orchards and vineyards
• Compatible in mixes with winter-annual clovers and medics

Annual Ryegrass (Italian Ryegrass)

Lolium multiflorum

• Winter-annual grass
• Introduced from Europe, naturalized in California
• *Lolium multiflorum* cvs include 'Astor' for coastal areas and 'Oregon Common' from the Willamette Valley, cultivars of *Lolium rigidum* include 'Wimmera 62' for low-rainfall areas
• Does well on heavy, waterlogged soils
• About 36-48" tall
• Biomass about 4,700-8,500 lb/acre
• N content about 1.3%
• Flowers May-June
• Often volunteers in vineyards, orchards on high-fertility sites
• May compete excessively with vines, necessitating intense mowing regimes

Barley (Common Barley)

Hordeum vulgare

• Winter-annual grass
• Native to Eurasia and Northern Africa, occasional escape in California
• Many cultivars; 'U.C. 476' commonly used; 'Solon' requires little water
• 24-48" tall
• Biomass 6,800-12,900 lb/acre
• N content 1.2%
• Does well on light, droughty soils, and on saline soils
• Flowers April-July
• Abundant bird cherry - oat aphid on panicles of 'U.C. 476'
• Does not self-reseed well
• Many cvs mature in early spring.

Bell Bean (Faba Bean, Horse Bean, Field Bean, Tick Bean)

Vicia faba

• Winter-annual legume
• Native to the Mediterranean region
• Many cvs; small-seeded cvs produce most biomass
• Heights vary greatly among cvs: 24-72 inches
• Biomass 4,900-8,100 lb/acre
• N content 1.2%
• Flowers about 40-60 days after sowing
• Does not tolerate close mowing
• Does not self-reestablish: requires annual sowing
• Does well on fertile, well-drained soils
• Harbors bean aphid and its predators
• Extrafloral nectaries on stipules attract lacewings, ants, and ichneumonid wasps

Berseem Clover

Trifolium alexandrinum

• Winter-annual legume
• Native to the Mediterranean region
• Cvs include 'Bigbee' and 'Multicut'
• Height of 'Bigbee' 24"

- Biomass up to 15,500 lb/ace with multiple mowings
- N content 2.6%
- Flowers May-June
- Tolerates close mowing
- Does not self-reestablish: requires annual sowing
- Does well on deep alluvial soils
- Tolerates alkalinity and salinity
- Harbors bigeyed bug (*Geocoris punctipes*), a beneficial predatory insect, in Georgia

Bur Medic or Bur Clover

Medicago polymorpha

- Winter-annual legume
- Native to the Mediterranean region
- Cvs include the early-maturing 'Serena', and the mid-season-maturing 'Circle Valley' and 'Santiago'.
- Flowers February-May.
- Seed mature late March-May
- Height is 14" in monoculture, taller when grown with oat
- Biomass production is up to about 8,300 lb/acre
- N content is 1.18-1.65%
- Tolerates low rainfall and grass competition better than subterranean clovers
- Tolerates clayey and sandy soils
- Rhizobia include alkaline- and acid-tolerant forms
- Has done well in orchards and vineyards in much of California, from southern California to Mendocino County
- Works well in mixtures with other winter-annual legumes and grasses in almond orchards
- Harbors abundant Lygus spp. in the spring

Cereal Rye (Rye)

Secale cereale

- Cool-season annual grass
- 36-72" tall
- Biomass 4,000-10,000 lb/acre
- N content 1%
- Flowers April-May
- Matures May-June
- Tolerates close winter mowing

•Self-reseeding
•'Merced' is drought tolerant; many cvs tolerate waterlogging
•Mature residue is slow to decompose
•Fibrous roots promote soil drainage
•Allelopathic to weeds
•Provides good structural support for vetches or pea
•Harbors bird cherry-oat aphid

Common Vetch

Vicia sativa

•Winter-annual legume
•Native to the Near East
•Flowers from April to July
•Seed matures from May to July
•Cvs include 'Languedoc', 'Vedoc', 'Willamette', and the hybrids 'Cahaba White' and 'Vantage'
•The close relative blackpod or narrowleaf vetch is termed *Vicia anugustifolia* or *Vicia sativa* ssp. *nigra*. This volunteers in the foothills and valleys of Central and Northern California
•Height is 22" in monoculture, but 72" may be attained if supported by tall cereal grain
•N content is about 4%
•Maximum biomass is about 8,000-9,000 lb/acre
•Tolerates many soil types, but needs good drainage
•Performs well as a self-reseeding cover crop in almond, prune, and well-lit walnut orchards and vineyards and in plow-down mixes for vegetable or field operations
•Seedlings apparently establish through dense walnut leaf litter better than do those of woollypod vetch, purple vetch, burr medic, subterranean clover, or crimson clover
•*Lygus* spp., adult aphidophagous hover flies, various ants (e.g., *Formica aerata, Solenopsis xyloni*), and various parasitic wasps are found at the extrafloral (stipular) nectaries
•Cowpea aphid often abundant on the terminals during spring
•Honeybees seldom visit the large blooms
•Some cvs (e.g., 'Cahaba White') are resistant to rootknot nematodes (*Meloidogyne* spp.).

Crimson Clover

Trifolium incarnatum

• Cool-season annual legume
• 12-20" tall
• Biomass 4,500-5,000 lb/a
• N content 2.4%
• Flowers April-May
• Matures May-June
• Taproot
• Hosts pea aphid and blue alfalfa aphid, prey to lady beetles
• Blossoms harbor flower thrips and pirate bugs
• Self-regenerating in North Coast vineyards
• Does not tolerate mowing as well as subclovers or medics

Mustards

Brassica spp.

• Several forms:
White mustard, *Brassica hirta*
Field mustard, *Brassica campestris*
Brown mustard, *Brassica juncea*
Black mustard, *Brassica nigra*
• Winter-annual brassicas
• Native to Asia, Europe, and North Africa.
• Strong taproot to depths of 1-3'
• Flowers February-May
• Heights:
White senf mustard, 12-28"
White mustard, 12-28"
Field mustard, 12-47"
Brown mustard, 12-47"
Black mustard, 20-98"
• Black mustard biomass about 12,000 lb/acre
• Black mustard N content about 3.5%
• Allelopathic chemicals produced by black and brown mustard suppress wheat germination
• Used in mixes with cereals and vetches
• Incorporated residues of brassicas produce sulfur compounds and cyanide gas as breakdown products of glucosinilates. This reduces some plant pathogens.

• Plowdown results in rapid breakdown of residue and few soil structural improvements, compared to barley or cereal rye.
• Flowers attract honeybees, lygus bugs, and hoverflies (Syrphidae)
• Field mustard a frequent volunteer in North Coast vineyards: early maturation renders reseeding compatible with mid-March plowdown.

Oat

Avena sativa

• Cool-season annual grass
• 24-60" tall
• Biomass 8,000-12,000 lb/a
• N content 1.2%
• Flowers April-May
• Matures May-June
• Fibrous root system
• Many cvs; 'Ogle' and 'Swan' have high biomass
• Not as tolerant of cold or waterlogging as cereal rye
• Harbors bird cherry-oat aphid

Purple Vetch

Vicia benghalensis

• Cool-season annual legume
• 23" but will climb
• Biomass 3,000-7,000 lb/a
• N content 4.3%
• Flowers April-May
• Matures May-June
• Tolerates moderately close mowing in winter
• Self-reseeding
• Has persisted well in orchards with heavy soil; tolerates waterlogging, but not freezes
• Residue decomposes rapidly

Rose Clover

Trifolium hirtum

• Native to the Eastern Mediterranean Region and Asia Minor
• Several cvs; 'Hykon' is earliest maturing and commonest form in commercial use

• Does well on acid, infertile, droughty, rocky soils
• Intolerant of flooding and of competition
• Taproot extends to over 78″ in depth
• Flowers from March through mid-May
• Seed matures in May and early June
• Height 3-18″
• Biomass 6,200 lb/acre
• N content 2%
• Sown in mixes with burr medic (*Medicago polymorpha*) and subterranean clover (*Trifolium subterraneum*).
• Used in some hillside vineyards in the North Coast and in almond orchards in Merced County
• Flowers contain abundant flower thrips (*Frankliniella* spp.) and minute pirate bug (*Orius tristicolor*).

Soft Chess

Bromus mollis

• Cool-season annual grass
• Native to Europe, naturalized in California
• Commercial cv is 'Blando'
• Height 8-31″
• Flowers April-July
• Biomass 9,500 lb/a
• N content about 1.9% at heading
• Among the best grass pollens for sustaining longevity and fecundity of the predatory mite *Euseius tularensis*
• Often used in self-reseeding orchard and vineyard cover crops, in mixes with vetches, medics, and clovers.
• Prone to lodge, not a good supporter for woollypod vetch

Sourclover

Melilotus indicus

• Winter-annual legume in most of California
• Native to Eastern Mediterranean region, Ethiopia, and India; naturalized in much of California
• Not currently in the seed trade
• 20″ tall
• Flowers April-October
• Seed mature in May-November

• Biomass up to 10,000 lb/acre
• N content 3.36%
• Tolerates floods and salinity
• Contains coumarin, the active principle in Warfarin®, toxic to rodents and livestock
• Formerly widely used in California citrus, in mixes with barley and purple vetch
• Blossoms attract few insects - - occasional bees

Subterranean Clover

Trifolium subterraneum

• Cool-season annual legume
• 6-15" tall
• Biomass is about 5,000 to 9,600 lb/a
• N content 2%
• Flowers March-May
• Matures April-June
• Tolerates close winter and spring mowing
• Self-reseeding
• Many cvs available with varying heights and maturity dates. 'Koala' and 'Clare' are tall, and have persisted well in orchards and vineyards with low to moderate soil fertility
• Used as a living or dying mulch with vegetables
• Tolerates orchard shade better than do vetches

Sweetclovers

Yellow sweetclover: *Melilotus officinalis*
White sweetclover: *Melilotus albus*

• Fall or spring-sown biennial legumes; annual forms of white sweetclover available (e.g., cv 'Hubam')
• Native to Eastern Mediterranean region, Ethiopia, and India; naturalized in much of California, especially in riparian zones
• Heights: yellow sweetclover 12-110"; white sweetclover 39-78"
• Flowers: yellow sweetclover May-August; white sweetclover May-September
• Seed mature in May-November
• Biennial forms of white sweetclover yield 2,200-3,500 lb/acre the first year and 2,200- 8,100 lb/acre the second; for yellow sweetclover the corresponding values are 4,200-4,500 and 5,500-8,500 lb/acre
• N content 2%

• Small seededness leads to slow establishment, sometimes necessitates barley as a nurse crop
• Strong taproot reputed to reduce clay pan problems
• Tolerate floods and salinity
• Contain coumarin, the active principle in Warfarin®, toxic to rodents and livestock
• Blossoms attract honeybees, tachinid flies, large predatory wasps, but not small wasps (e.g., *Aphytis* sp. wasps, a parasite of San Jose scale)
• Rarely used as a cover crop in California, except in insectary mixes

Tansy Phacelia

Phacelia tanacetifolia
• Cool-season annual forb
• Native to California, but developed in Germany
• 12-36" tall
• Biomass 3,300-6,000 lb/a
• N content 4%
• Flowers March-May
• Matures April-June
• Grown as a nitrogen catch crop and as a nectar source for honeybees and hover flies
• Harbors lygus bugs
• Used as nectar and pollen source by blue orchard bee (*Osmia lignaria propinqua*)

Woollypod Vetch

Vicia villosa* ssp. *dasycarpa
• Cool-season annual legume
• 18-27" tall, but will climb
• Biomass 6,000 lb/a
• N content 4.2%
• Flowers March-May
• Matures April-June
• Tolerates moderately close mowing in winter
• Self-reseeding
• 'Lana' is only commercial cv.
• Has persisted well in orchards with high and low fertility, with light and heavy soils
• Residue decomposes rapidly

- Aggressive climber
- Used as nectar, but not pollen, source by blue orchard bee (*Osmia lignaria propinqua*)