630 US ISSN 0271-9916 August 1988 RESEARCH EXTENSION SERIES 094

COVER CROPS FOR ORCHARDS IN HAWAII

Dale O. Evans, Robert J. Joy, and C. L. Chia

HITAHR · COLLEGE OF TROPICAL AGRICULTURE AND HUMAN RESOURCES · UNIVERSITY OF HAWAII

The Library of Congress has catalogued this serial publication as follows:

Research extension series / Hawaii Institute of Tropical Agriculture and Human Resources.–001–[Honolulu, Hawaii]:
The Institute, [1980–
v. : ill. ; 22 cm
Irregular.
Title from cover.
Separately catalogued and classified in LC before and including no. 044.

ISSN 0271-9916 = Research extension series - Hawaii Institute of Tropical Agriculture and Human Resources.
1. Agriculture–Hawaii–Collected works. 2. Agriculture–Research–Hawaii–Collected works. I. Hawaii Institute of Tropical Agriculture and Human Resources. II Title: Research extension series - Hawaii Institute of Tropical Agriculture and Human Resources
S52.5R47 630'.5–dc19 85-645281
AACR 2 MARC-S
Library of Congress [8506]

AUTHORS

Dale O. Evans is a research associate in the Department of Horticulture, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa.

Robert J. Joy is a plant materials specialist, USDA Soil Conservation Service, Plant Materials Center, Hoolehua, Molokai.

C. L. Chia is an extension specialist in the Department of Horticulture, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa.

CONTENTS

Tables

Figures

COVER CROPS FOR ORCHARDS IN HAWAII

Dale O. Evans, Robert J. Joy, and C.L. Chia

INTRODUCTION

Many reasons justify planting and maintaining ground cover crops in tree orchards. These reasons include the actions of covers in preventing soil erosion, suppressing weeds, maintaining soil structure, providing easier access during wet weather, and contributing to soil fertility through organic matter. The most appropriate cover crop species and practices differ depending on the orchard site, type of tree crop, and stage of orchard development. Success with cover crops depends on proper selection of plant species and on skill in establishing and managing them.

Experience with cover crops in fruit tree plantings in Hawaii is limited. The information presented here may provide a basis for growers to expand local experience with cultural practices using cover crops for soil management in orchards. Suggested species or practices should be tested in trial sections of orchards before widespread application.

SOIL COVER MANAGEMENT CHOICES

Maintaining a bare soil surface, or "clean cultivation," is frequently advocated for orchard crops. Drawbacks associated with cover crops include competition for plant nutrients, competition for water during periods of drought, interference with harvesting, harboring of pests or disease vectors, increased management cost and complexity, and sometimes the lack of registered pesticides for cover crop control or protection that are approved for use in plantings of the associated crop. The alternative of clean cultivation is often costly, usually inconducive to maintaining favorable soil conditions, and almost always undesirable in areas prone to erosion. Much research indicates that, when feasible, growing a cover crop is preferable.

Another alternative to planted cover crops is "natural regeneration," allowing some or all of the preexisting vegetation to come back after the initial land clearing. With this method, aggressive and hard-to-control weeds may invade the area. This method usually implies a lack of management, and although it fulfills some of the desired functions of a cover crop, it has many disadvantages.

Planted cover crops are characterized by the type of plant used: grasses, legumes, or mixtures of both. Grasses are often low-maintenance covers that are very effective in binding the surface soil. Grass-legume mixtures are desirable because of the nitrogen (N) contribution of the legume. Legumes are widely used as cover crops under Asian plantation crops, where they have been found to contribute effectively to soil N and protect the soil from erosive forces. In Southeast Asia, maintaining legume cover crops is standard practice during the establishment of rubber and oil palm, and the covers are often grazed by livestock.

The appropriate grass or legume species for a given soil-climate site must be found by trial. Once the successful species are identified, cover crops provide many benefits during orchard establishment. As the orchard matures and the tree canopy closes, increasing shade causes most cover crop species to die out.

BENEFITS OF COVER CROPS

Cover crops have been found to be superior to bare soil in maintaining or improving soil structure and preventing soil erosion. A living cover crop slows drying of the soil and protects its surface from becoming sealed by the impact of raindrops. Its roots penetrate the soil and after decaying form channels, opening the soil to deeper levels. Improved soil aggregation and total porosity reduce runoff and allow both water and air to enter the soil more freely.

Cover crops can maintain or increase the amount of soil organic matter and increase soil nutrient availability. When lands are cleared for new plantings, soil organic matter is mineralized at higher rates and nutrients can be lost by leaching beyond the root zone. Cover crops help to replace the original vegetation in its function as nutrient storage pool by capturing newly mineralized nutrients and preventing leaching losses. Leaf drop from the cover crops adds organic matter to the soil surface upon decay. Higher soil calcium (Ca), magnesium (Mg), and potassium (K) levels have been found under leg-

ume covers compared to bare soil in rubber plantings. Adding organic matter increases the reserves of soil N. Organic matter aids surface soil aggregation and helps prevent crusting.

Soil organic matter may help to control soilborne plant diseases. Saprophytic organisms that decompose organic matter may compete with or parasitize pathogens and may produce antipathogenic toxins. The rich organic soil horizon that can develop under a cover crop may be a relatively pathogen-free zone where new roots can develop.

LEGUMES AS COVER CROPS

Legumes provide N through biological fixation in their root nodules. The N is continually cycled from the legumes to the soil by leaf litter fall and root and nodule decay. During the approximately five-year establishment phase of Asian rubber or oil palm plantings, legume covers reportedly contribute an amount of N equivalent to 900 lb/ac of urea before they are shaded out.

Two types of legumes are used as covers: those with a prostrate or semiprostrate growth habit and those with an erect or shrubby growth habit. Table 1 lists legumes of both types that may be considered for trial as cover crops in orchards.

Prostrate or Semiprostrate Legumes

The prostrate or semiprostrate legumes are the types most frequently used as cover crops. Many legumes in this category have a creeping or twining growth habit. Annual species have rapid growth providing quick soil protection, but they do not persist unless they are self-sowing under the growing conditions or are replanted each year. Perennial species establish more slowly but persist longer. When annuals and perennials are mixed, the perennials take over as the annuals die. Shade tolerance is variable among these legumes. Mixtures of species that have varying shade tolerances may be sown, so that some species persist for a period after others are shaded out.

Experience with prostrate and semiprostrate legumes as cover crops in Hawaii is limited. Velvet beans (*Mucuna* species) and the dolichos or hyacinth bean (*Lablab purpureus*) are two annual types that establish cover rapidly and can be vigorous in smothering weeds. The sarawak bean (*Vigna hosei*) is a perennial low-growing creeping cover crop species. *Desmodium* species are also potentially useful as cover crops. The perennial creeping legumes used as cover crops in Southeast Asian rubber plantings are *Centrosema pubescens*, *Pueraria phaseoloides*, and *Calopogonium mucunoides*, which have not been extensively grown in Hawaii.

Creeping and twining legume species should be used with caution. The grower should have enough experience with them to be sure that they can be controlled mechanically or with herbicides. Neglect in management may result in the cover overtaking the tree crop, necessitating removal from the trees by hand. Thick mats of twining legumes may bind up mowing equipment. Trial plantings are important to gain familiarity with the cover species before widespread sowing.

Erect Legumes

The erect legumes are not suited as permanent ground covers but may be grown in interrow spaces of orchards as temporary cover crops, green manure crops, or sources of mulch. Two species for low- to mid-elevation areas of Hawaii are sunn hemp (*Crotalaria juncea*), an annual, and pigeon pea (*Cajanus cajan*), a short-lived perennial.

Erect legumes can help prepare lands to establish other, permanent cover crops. Sown thickly, they form dense stands and suppress weeds. When mown or pushed over, they form a mulch. As the mulch decomposes, cover crop seed can be broadcast when contact with the soil is assured. This method could be used in interrows in a developing orchard or as a preliminary step in orchard establishment after land clearing.

Pigeon pea is a deep-rooted woody shrub that is drought-tolerant once established. It was formerly grown as a green manure in Hawaii to restore soil fertility after pineapple and other crops. Most varieties found in Hawaii reach a height of 6–8 feet and may be cut periodically. Plants spaced 4–6 inches apart in rows 24–30 inches apart should provide a thick cover.

Sunn hemp is a fast-growing annual green manure legume. The cultivar 'Tropic Sun' is available in Hawaii (Rotar and Joy 1983). When sown in spring or summer under appropriate conditions, 'Tropic Sun' develops a stand 5 feet high or more within seven to eight weeks from sowing. At that stage, its stems begin to lignify and the plants are at the proper stage to use as mulch. Sunn hemp may be a suitable interrow-planted mulch source for developing orchards. It should be sown thickly, so that plants are 6 inches apart or less.

Growers considering pigeon pea or sunn hemp should have equipment heavy enough to mow or knock over the plants. With light equipment, timing of control becomes important, so that the plants do not become too woody. High sowing rates may result

in delaying the onset of stem woodiness. Stands allowed to grow tall may be hard to kill with conventional herbicide spray equipment.

GRASSES AS COVER CROPS

Grasses are excellent cover crops for orchards because they are dense, compete with weeds, resist wear from traffic, and are adapted to mowing. Species suggested for trial in orchards are listed in Table 2. Grasses successfully used as permanent ground cover in Hawaii are 'Pensacola' bahiagrass (*Paspalum notatum*), bermudagrass (*Cynodon dactylon*), carpetgrass (*Axonopus affinis*), centipedegrass (*Eremochloa ophiuroides*), 'Tropic Lalo' paspalum (*Paspalum hieronymii*) (Rotar and Joy 1984), hilograss (*Paspalum conjugatum*), kikuyugrass (*Pennisetum clandestinum*), pangolagrass (*Digitaria decumbens*), saint augustinegrass (*Stenotaphrum secundatum*), and stargrass (*Cynodon plectostachyus*).

Annual grasses such as wheat, oats, and annual rye, or a combination of one of these with an annual legume such as vetch, are often recommended to be sown in mixture with perennial grasses and legumes that are slow to establish, particularly when planted as sprigs. The annuals provide soil cover until the perennials become established.

ESTABLISHING COVER CROPS

Rapid cover establishment in new plantings is desirable to protect the soil and reduce the period of erosion hazard. When preparing lands to sow cover crops, the more extensive the cultivation, the greater the subsequent erosion hazard. Disturbance of the soil surface should therefore be the minimum needed to establish the cover crop.

Existing vegetation should be killed before sowing cover crops. In some cases, the dead weed cover can be left to protect the soil surface. Cover crop seeds are then broadcast at heavy rates without any tillage. This method works well as long as the dead weed mulch is light enough to allow seeds to contact the soil but heavy enough that the soil surface remains moist beneath it so the seeds can germinate.

Drilling with a heavy-duty seed drill is another method of seeding. With this method, cultivation can usually be limited to ripping or disking. Compared to drilled seed, broadcast seed generally requires more thorough seedbed preparation to ensure seed burial beneath the soil surface. Ripping or disking the soil may suffice when broadcasting, depending on the kind and size of seed planted, the soil condition, and the amount of vegetation present. The erosion hazard can be minimized when broadcasting by tilling and seeding narrow strips, 5–10 feet wide, between tree rows and leaving the remainder undisturbed until the cover crop is established. A cultipacker-seeder is preferred for broadcasting. When tilling in existing orchard plantings, care should be taken to avoid damaging the tree roots. Heavy seeding rates are advised when planting cover crops, and rates for broadcasting are higher than for drill-sowing.

In calculating sowing rates, the amount of pure live seed (PLS) in a seedlot should be considered. Pure live seed is the most useful expression of seed quality: percent PLS = (percent germination × percent purity)/100. Percent purity is the proportion of a seedlot that is actual seed of the desired plant. Percent germination is the proportion of actual seed that is viable, or in other words is alive and will germinate. If, for example, PLS of a seedlot is 80 percent and recommended sowing rate is 50 lb/ac, then the amount of seed used should be increased to 62.5 lb/ac (50/0.8 = 62.5).

Legume seeds require special treatment. Many, but not all, types need to be scarified before planting. This involves breaking seed dormancy by mechanically or chemically abrading the seed coat so water can penetrate it and the seed can germinate. Proper scarification ensures that the viable seeds will all germinate when watered. Mechanical methods include lightly scratching the seed coats by rubbing them between blocks of sandpaper or tumbling the seeds in a container with sharp gravel. Chemical methods involve soaking seeds in acids, which are dangerous if not properly handled.

A simpler method is hot water treatment, in which boiling water is poured over the seeds and allowed to cool. This may work for some species but may kill others. If this method does not break dormancy, it may help to keep the water boiling for a short period after immersing the seeds. The treatment time will vary, depending on the legume. Before treating large seedlots, experiment with small ones to find a method that scarifies adequately without harming the seeds. Seeds may be germinated on moist paper towels to determine the trial results. If they swell within 24 hours, the seeds have been adequately scarified. If the seed is alive, the root should emerge about 24 to 48 hours after seed swelling.

Legume seeds or sprigs should be inoculated with *Rhizobium* bacteria at the time of planting. This helps to ensure that the plants will be effectively nodulated and able to fix N from the air. The correct type of *Rhizobium* for a particular legume may not be naturally present in the soil. Inoculants for many varieties of legumes are available through seed suppliers.

When propagating covers vegetatively, sprigs are usually planted by hand or with a mechanical sprig planter in rows 2–3 feet apart. Seedbed preparation for sprigging should be no more than the required minimum. Overseeding with a fast-growing annual cover crop is advised when necessary to reduce erosion hazard.

Fertilizers can help to ensure rapid cover crop establishment when soil tests indicate their need. Legumes require more soil Ca than grasses; they also need adequate levels of the micronutrient molybdenum (Mo) for their N fixation process. Both grasses and legumes especially need phosphorus (P) for root development. On acid soils with phosphate fixation capacities, initial P application rates required may be high in order to satisfy that capacity and provide available phosphate as well. These applications will be of long-term benefit to the orchard, since P is not readily lost from the soil. Grasses require N fertilizer applications on most soils, and legumes may also benefit from judicious applications of "starter N." When legumes and grasses are drilled, fertilizers may be banded along the rows beneath and to the side of the seed rather than broadcast over the entire soil area.

During cover crop establishment, weed control is usually needed to ensure a pure stand, particularly with the slower-growing perennial prostrate or creeping species. When cover crop growth is vigorous, most creeping legumes suppress weeds by climbing on any plants that rise above the canopy.

MANAGING COVER CROPS

Cover crops grown in orchards will flourish only when adequate soil moisture and plant nutrients are available, and they may compete for these with the orchard crop. Management skill is required to regulate the growth of the cover crop to maximize benefits to the orchard.

Control of the established cover crop will be necessary if rank growth competes with or overtakes the associated tree crop. Mowing the cover crop or circle-weeding around trees may be required, especially in young orchards. Particular attention must be paid to legumes with a twining habit. If not contained either chemically or mechanically, they may climb on the trees and must then be pulled off by hand. Under certain conditions, requirements for control of twining legumes may decrease as the trees become larger. For example, observations of glycine (*Neonotonia wightii*) and sarawak bean indicate that they do not readily twine on trees with a trunk diameter of 6 inches or more, relatively smooth bark, and no low branches.

Cover crops grown in strips between the tree rows may be the easiest to manage. Strips immediately under the trees are kept free of vegetation either mechanically or with approved herbicides (Figure 4). The cover crop in the interrow is periodically mown. This method prevents twining, reduces competition for nutrients and water, makes mowing easier, and reduces rodent damage. In new orchard plantings, strip cover patterns may be obtained by first planting the cover crop over the entire area, then cultivating or applying a registered herbicide to create strips in the established cover before sowing or transplanting the tree crop.

One method of weed control in stands of prostrate legumes is to kill weeds emerging above the canopy, using a tractor-mounted absorbent wick applicator bar carrying a registered herbicide. The bar is drawn over the cover so as to contact the taller weeds but not the cover crop. Another possible use of registered herbicides on vigorous creeping covers would be to apply levels low enough to reduce growth but not to kill the legumes. This could be of value during summer months, when growth may be faster than desired. The exact application levels for this purpose would have to be found by trial on small test areas.

Some of the crops discussed above, particularly the fast-growing annual legumes such as *Mucuna*, *Lablab*, and sunn hemp, can be disked or plowed into the soil as green manure crops. They decompose rapidly when incorporated into the soil in young, succulent growth stages. After they have lignified, they decompose less readily and can make a longer-lasting contribution to the soil organic matter. Mature plants may be more difficult to mow or incorporate into the soil, and heavier equipment may be needed. Cover crops grown to be used as surface mulch should be lignified, so they remain longer on the soil surface.

SUMMARY OF GUIDELINES FOR GROWING COVER CROPS

Sow trial plantings to make sure the plants are adapted.

Test the soil. Apply fertilizers and lime as needed.

Check seed viability before sowing. Increase the seeding rate as appropriate after determining the percentage of pure live seed.

Scarify legume seed if necessary to ensure complete and uniform germination.

Inoculate legume seed with an appropriate strain of *Rhizobium* bacteria immediately before sowing.

Sow when rainfall is expected or irrigation is available. If moisture is adequate, spring and summer are the best seasons for growth and establishment of tropical plants; short days and cool weather usually reduce growth. Temperate plants such as trefoil, white clover, vetch, rye, and wheat prefer cool weather. Avoid sowing in dry periods.

Plan to control weeds if necessary to ensure a pure stand of the cover crop.

Plan to establish permanent cover crops in new orchards before the trees are planted.

Consult your local Soil Conservation Service and Cooperative Extension Service offices for assistance in planning for effective soil management with cover crops.

COVER CROPS IN AVOCADO PLANTINGS

Managing soil organic matter in the avocado orchard is a concern of many growers. Of special importance to the avocado plant is the possibility that certain practices can reduce avocado root rot (*Phytophthora cinnamomi*) or its damage.

Increased water penetration is a major benefit of cover crops. Good soil drainage and the absence of waterlogging are important for avocado root rot control. Application of N-rich organic materials has been recommended in California and Australia to prolong the life of avocado trees infected with *Phytophthora* (Borst 1986).

Mulching under avocado is believed to create "*Phytophthora*-suppressive" soil conditions that may enable avocado trees to survive despite *Phytophthora* infestation. Mowing covers planted in interrows and applying the material as mulch under the trees is possible on relatively level lands. On sloping lands or in mature orchards without interrow space, mulch crops grown elsewhere can be brought in. Sunn hemp may be a good crop for this purpose.

Caution is advised when cultivating in avocado plantings, whether for weed control or for sowing and managing cover crops. Mechanical damage to the avocado root system encourages *Phytophthora* infection. Disking or plowing to manage covers should be confined to interrow spaces beyond the avocado root zone.

COVER CROPS IN BANANA PLANTINGS

Cover crops are generally not used in banana plantings in Hawaii, although they should be given more consideration. In Taiwan, where seasonal typhoon storms cause bananas to be replanted on an annual cycle, erect legumes such as *Sesbania cannabina* are sown in the interrows when the new seedpieces are transplanted. The legumes help suppress weeds and are subsequently tilled in as green manure or used as mulch. This practice may be useful for new plantings in Hawaii, using legumes such as sunn hemp and pigeon pea. The legume 'Siratro' (*Macroptilium atropurpureum*) used as a cover crop is reported to suppress an important pest of bananas, the burrowing nematode (*Radolphus similis*).

Centro (*Centrosema pubescens*) was formerly used as a permanent cover crop in Taiwan. Its use declined because its climbing habit required more intensive management than did other covers. It was also found that substances extracted from its roots, stems, and leaves had a toxic effect on banana plants and caused poor growth.

Soil conservation research in Taiwan has shown that bahiagrass (*Paspalum notatum*) is a desirable cover crop. Although its daily water consumption is relatively high during periods of vigorous growth, bahiagrass tolerates shade and a wide range of soil pH. It improves soil aeration and permeability. The bahiagrass is mowed and the mowed material used as mulch under the tree canopies. This cover/mulch technique has been an excellent erosion control method for bananas, citrus, and litchi plantations on steep slopes in Taiwan.

COVER CROPS IN MACADAMIA PLANTINGS

Macadamia orchards can benefit from cover crops, particularly on slopes where erosion can be serious (Figure 2). Theoretically, a tight, well managed cover can increase nut recovery. During wet weather, an estimated 5 percent of the nut crop may be buried in mud and lost. Cover crops may improve access for mechanical nut sweepers, which will not work on deep muddy soils. An appropriate cover crop would provide a harvestable surface by holding the nuts off the ground, increasing mechanical or hand harvesting efficiency. Cover crops may also increase mechanical harvesting efficiency in orchards with a cinder floor by eliminating or reducing the number of

Figure 1. A mixture of common pangola and hilograss in a guava orchard.

Figure 2. Erosion and one of its consequences in a macadamia orchard.

Figure 3. Complete cover of the orchard floor in a young macadamia orchard.

Figure 4. Strip cover management in a young bearing macadamia orchard.

nut-sized cinders swept into the windrow and harvested with the nuts.

Maintaining an effective vegetative cover in mature macadamia orchards has been difficult because of the high degree of shading under the dense tree canopy. Efforts to find the ground cover plant that combines sufficient shade tolerance with other desired characteristics have not been entirely successful.

Criteria and priorities for ground cover selection have been:

1. Provide a harvestable surface.
2. Tolerate shade.
3. Compete with weeds.
4. Have low growth.
5. Control erosion effectively.
6. Resist insects and plant diseases.
7. Require only low maintenance for mowing and fertilization.
8. Tolerate traffic.
9. Establish easily.
10. Provide rapid ground coverage.
11. Tolerate drought.
12. Provide dense cover.
13. Root at nodes.
14. Give low competition with trees.
15. Be nonclimbing (legumes).
16. Provide high N fixation (legumes).

'Tropic Lalo' paspalum and hilograss are two grasses with most of the desired characteristics. 'Tropic Lalo' provides a denser cover than hilograss but is less tolerant of drought or shade. Neither plant has enough drought tolerance for the lowest rainfall areas or enough shade tolerance for mature orchards, which produce essentially complete shade. Bermudagrass and stargrass are drought-tolerant and are used for young orchards in low-rainfall areas but lack the shade tolerance needed when the macadamia trees mature. Two legumes adapted to medium- to high-rainfall areas are three-flowered beggarweed (*Desmodium triflorum*) and hetero (*Desmodium heterophyllum*). They may be planted with grasses to add N but are not competitive or durable enough to be planted alone.

A factor to consider in using legumes such as *Desmodium* species is their potential to host the southern green stink bug (*Nezara veridula*), a pest of macadamia. The damage by stink bugs to macadamia nuts usually occurs during the early part of the fruiting cycle, between anthesis and shell hardening. Most legumes, unlike grasses, attract the stink bug, but legume species vary in suitability as stink bug hosts. Less suitable hosts such as the desmodiums attract the stink bugs but are not a good food source for them, so the insects are more likely to move off these legumes and onto the macadamia trees. Other legumes that are suitable hosts hold the insects by providing a food source. If these covers are mown near the time of macadamia anthesis, however, the mowing may force the pests into the trees. The risks of crop losses and potential expenses for controlling stink bug infestations should be weighed against advantages of using legumes as cover crops under macadamia.

The shading problem in mature orchards might be alleviated by spacing the trees as far apart as possible. Experience indicates, however, that a plant population providing an economic nut yield will eventually produce virtually complete shade. Tree spacings for commercial orchards in Hawaii range from approximately 18 × 25 feet to 30 × 35 feet. Trials have been conducted with spacings ranging from 25 feet to 50 feet between rows. Fifty feet between rows is apparently too wide and results in lower yields. It is generally believed that nut production will be essentially the same over a fairly wide plant population range after the trees mature, provided that a full canopy is developed. Growers sometimes use higher tree numbers per unit area to increase early nut production.

To maintain a permanent ground cover strip at least 5 feet wide between tree rows in mature orchards, certain measures appear necessary to allow enough light to reach the orchard floor. Among these are wider row spacings (at least 30 feet between mature trees), staggered rows, vertical hedging of trees, and use of macadamia cultivars with a compact, upright canopy rather than those with a wide, spreading canopy. These measures may not be compatible with orchard practices set by economic or production considerations, but some combination of them may be required to obtain good growth of ground covers. Because the harmful effects of soil erosion on land productivity are usually expensive to correct and are often irreversible, the need for ground covers in situations with an erosion hazard should be seriously considered.

COVER CROPS IN COFFEE PLANTINGS

Commercial coffee-growing in Hawaii has for many years been conducted almost exclusively in the Kona area of the island of Hawaii. Kona's "coffee belt" is a strip of land about two miles wide running almost parallel to the coastline between about 700 feet and 2000 feet elevation. Although the land planted to coffee in Kona is quite steep, the volcanic

soil on much of the area is very porous lava. Erosion has not been a problem, and most growers have practiced clean cultivation. Recent plantings in Kona and other areas in the state, however, are on mineral soils that are more erosive and should be protected by a ground cover. The cover should be planted after the land is cleared and before the coffee is planted.

Carpetgrass is adapted to the coffee-growing area in Kona and is being used successfully by growers. Carpetgrass is easily established from seed and maintained by mowing. Herbicides, mechanical weeding, and hand weeding are used to reduce competition immediately around the coffee plants. 'Tropic Lalo' paspalum may be more appropriate for access roads and other areas that bear equipment traffic, because it is more wear-resistant than carpetgrass. 'Tropic lalo' must be sprigged, but it establishes easily and covers the ground fairly rapidly. Legumes that appear to have the most promise are those of the genus *Desmodium*. Legume seeds may be sown with the grass seeds or overseeded after sprigging the grass.

LITERATURE CITED

Rotar, P. P., and R. J. Joy. 1983. 'Tropic Sun' Sunn Hemp: *Crotalaria juncea* L. Hawaii Institute of Tropical Agriculture and Human Resources, University of Hawaii. Research Extension Series 036.

Rotar, P. P., and R. J. Joy. 1984. 'Tropic Lalo' Paspalum: *Paspalum hieronymii* Hack. Hawaii Institute of Tropical Agriculture and Human Resources, University of Hawaii. Research Extension Series 046.

Borst, G. 1986. Using organic supplements to enhance fungi control. California Grower, 10(1):36, 40, 43.

Table 1. Promising legumes for cover crops.

Scientific Name	Common Name/ Cultivar	Description	Elevation Range (ft)	Rainfall Range (in/yr)	Broadcast Seeding Rate*
Cajanus cajan	Pigeon pea	Tropical perennial, short-lived shrub. Varieties range from 2 ft to 12 ft high.	0–3000	30–80	60
Calopogonium caeruleum and *C. mucunoides*	Calopo	Tropical perennial. Creeping and twining habit. Roots at nodes. Thick foliage 18 in to 36 in high. *C. caeruleum* is more shade- and drought-tolerant.	0–2500	35+	30
Centrosema pubescens	Centro 'Belalto'	Tropical perennial. Creeping and twining. Roots at nodes. Dense cover up to 18 in high. Shade tolerant.	0–2500	60+	20
Crotalaria juncea	Sunn hemp 'Tropic Sun'	Tropical erect, branching annual. Fast-growing, 4 ft to 6+ ft high. Simple elliptical leaves.	0–2000	30–80	60
Desmodium aparines (syn. *D. intortum*)	Desmodium 'Kuiaha' 'Greenleaf'	Tropical perennial. Forms dense cover up to 36 in high. Creeping, roots at nodes, does not twine. Seed pods adhere to clothing. A good nitrogen fixer.	0–2500	35+	20
Desmodium canum	Kaimi clover 'Tifhardy 1'	Tropical perennial. Creeping, nontwining, up to 24 in high. Seed pods adhere to clothing. Combines well with grasses. Tolerant of poor soils.	0–3000	35+	20
Desmodium heterophyllum	Hetero 'Johnstone'	Tropical perennial creeper. Fine stems, freely branching, hairy. Roots at nodes. Forms thick mat 12 in to 18 in high. Nontwining. Seed pods do not adhere. Combines well with grasses. Somewhat shade tolerant.	0–2500	60+	20

*Broadcast seeding rates are in pounds of pure live seed (PLS) per acre.

Table 1. Promising legumes for cover crops. (Cont.)

Scientific Name	Common Name/ Cultivar	Description	Elevation Range (ft)	Rainfall Range (in/yr)	Broadcast Seeding Rate
Desmodium ovalifolium	Ovalifolium	Tropical perennial creeper, 12 in to 24 in high. Trifoliate leaves with oval leaflets. Non-twining. Pods adhere somewhat but should not be objectionable.	0–2500	60+	20
Desmodium triflorum	Three-flowered beggarweed	Tropical creeper, forming a low, dense mat about 4 in high. Grows well with grasses. Fine stems, small trifoliate leaves.Seedpods do not adhere.	0–2500	35+	20
Indigofera spicata (syn. *I. endecaphylla*)	Creeping indigo	Tropical prostrate, low-growing perennial, non-twining. Resists control with herbicides. Some strains may be toxic to livestock. Grows well with mown grasses.	0–1000	25+	20
Lablab purpureus (syn. *Dolichos lablab*)	Hyacinth bean Lablab 'Rongai' 'Highworth' 'Tift 1'	Tropical annual or biennial. Large trifoliate leaves and large seeds. Drought-tolerant. Forms a dense cover 3 ft to 4 ft high. Climbs over weeds but does not twine.	0–3000	20–60	60
Lotononis bainesii	Lotononis 'Miles'	Tropical creeping, prostrate perennial. Slender, irregularly branched stems. Forms a dense cover about 24 in high when combined with a grass. Essential that seed be coated with correct legume inoculant.	0–2500	35–60	10
Lotus pedunculatus	Big trefoil 'Grasslands Maku'	Perennial, native to southern Europe and temperate Asia. Spreads by stolons and rhizomes. Grows well in association with grasses. Grows to 24 in high.	1500-6000	50+	25

Table 1. Promising legumes for cover crops. (Cont.)

Scientific Name	Common Name/ Cultivar	Description	Elevation Range (ft)	Rainfall Range (in/yr)	Broadcast Seeding Rate
Macroptilium atropurpureum	'Siratro'	Tropical creeping, twining perennial. Makes fast initial growth. Drought-tolerant. Resistant to rootknot (*Meloidogyne* spp.) and burrowing (*Radolpholus similis*) nematode. Forms dense mat 24 in to 30 in high.	0–2500	15–60	40
Mucuna species	Velvet bean	Tropical creeping, twining annuals. Vigorous-growing, fast-spreading. Forms mat 2 ft to 3 ft high. Large trifoliate leaves and large seeds.	0–2500	50+	60
Neonotonia wightii (syn. *Glycine javanica*, *G. wightii*)	Glycine 'Tinaroo' 'Cooper' 'Clarence' 'Malawi'	Tropical trailing, twining perennial. Drought- and shade-tolerant. Dense cover 18 in to 24 in high. Initial growth is relatively slow.	0–3000	15–60	40
Sesbania cannabina (syn. *S. bispinosa*, *S. aculeata*)	Sesbania Daincha	Tropical erect, branching annual with pinnate leaves; native to Asia. Fast-growing, to 6+ ft high. Tolerates soil salinity, waterlogging, and flooding. Many types, with varied seeding habits.	0–2000	30–80+	35
Stylosanthes guianensis	Stylo 'Cook' 'Endeavour' 'Oxley' 'Schofield'	Tropical perennial, native to Latin America. Semiprostrate, woody stems. Normal height is 2 ft or more, although 'Oxley' has prostrate stems about 12 in high when grown alone. Stylo tolerates acidity, low fertility, and poor drainage. Should be grown in combination with a grass for best cover. 'Oxley' is reported to be more drought-tolerant than the other cultivars.	0–3000	60+	25

Table 1. Promising legumes for cover crops. (Cont.)

Scientific Name	Common Name/ Cultivar	Description	Elevation Range (ft)	Rainfall Range (in/yr)	Broadcast Seeding Rate
Trifolium repens	White clover Common white Dutch 'Haifa' 'Grasslands Huia'	Prostrate perennial, native to Europe. Forms dense growth about 18 in high. Combines well with associated grasses.	1500–7000	35–80	25
Vicia benghalensis *Vicia sativa* *Vicia villosa*	Purple vetch Common vetch Winter vetch 'Lana' 'Namoi'	Semiprostrate annuals, native to Europe, Asia, Africa. Relatively fine, trailing stems may grow 3 ft long or more and normally 1 ft to 2 ft high when growing alone. Provides cover for up to 9 mo. Combines well with annual grasses such as oats, wheat, and rye for soil improvement or to provide rapid cover until slower-growing perennials become established. Adapted to areas above 2000 ft elevation with at least 35 in annual rainfall. 'Lana' and 'Namoi' may be grown at any elevation during the winter months.	0–4000	35+	60
Vigna hosei (syn. *Dolichos hosei*)	Sarawak bean	Tropical, low-growing perennial with trailing, twining growth habit. Forms thick ground cover 6 in to 12 in high. Prefers acid soil (pH 4.9 or less). Propagated by seed or sprigs. Minimum sprigging distance: 3 ft by 3 ft.	0–2500	50+	35

Table 2. Promising grasses for cover crops.

Scientific Name	Common Name/ Cultivar	Description	Elevation Range (ft)	Rainfall Range (in/yr)	Broadcast Seeding Rate*
Axonopus affinis and *A. compressus*	Narrowleaf carpetgrass Broadleaf carpetgrass	Native to southern United States and the West Indies. Provide tight cover. Propagated by seed or sprigs. Low-growing, to about 12 in; fairly low-maintenance. Tolerate low soil fertility. Combine well with trefoil, *Desmodium* spp., and white clover. *A. compressus* has wider leaves, is more shade-tolerant, and is more palatable to animals than is *A. affinis*. The former produces few seeds and is usually propagated by sprigs. Plant sprigs 2 ft by 2 ft or closer.	0–4000	50+	40
Cenchrus ciliaris	Buffelgrass 'T4464' (American) 'West Australian' 'Gayndah'	Bunch grass native to tropical and subtropical Africa, India, and Indonesia. Very drought-tolerant, recommended for areas too arid for bermudagrass. Propagated by seed. Combines well with legumes glycine and 'Siratro'. Cultivars 'T4464' and 'Gayndah' grow to 36 in high; 'West Australian' grows 15 in to 30 in high.	0–3000	10–35	20
Cynodon dactylon	Bermudagrass Common bermudagrass 'NK37'	Very adaptable. Native to Africa and India. Drought- and salt-tolerant. Propagated by seed or sprigs. Slow from seed, but once established, it spreads rapidly. Combines with most legumes. 'NK37' is a "giant" pasture type growing 18 in to 24 in high. Common is a turf type growing to about 12 in high. Plant sprigs 3 ft by 3 ft or closer.	0–3000	20–50	35
Cynodon plechtostachyus	Stargrass	Native to Africa. Similar in growth to giant bermudagrass but more vigorous. Provides dense growth about 30 in high. Fast-growing. Propagated by sprigs; plant 3 ft by 3 ft or closer.	0–3000	20–80	—

*Broadcast seeding rates are in pounds of pure live seed (PLS) per acre.

Table 2. Promising grasses for cover crops. (Cont.)

Scientific Name	Common Name/ Cultivar	Description	Elevation Range (ft)	Rainfall Range (in/yr)	Broadcast Seeding Rate
Digitaria decumbens	Digitgrass Pangolagrass 'Transvala' 'Mealani' Common pangola	Native to South Africa. Forms dense cover 24 in to 36 in high. 'Transvala' is somewhat lower-growing than other cultivars. 'Mealani' resists leaf rust. Propagated by sprigs; plant 3 ft by 3 ft or closer.	0–2500	40+	—
Eremochloa ophiuroides	Centipedegrass	Low-growing, to about 8 in high. Low-maintenance. Slow-spreading, shade-tolerant. Propagated by seed or sprigs. Plant sprigs no wider than 2 ft by 2 ft.	0–2500	35+	20
Lolium multiflorum	Annual ryegrass	Native to southern Europe. Rapid establishment and growth. May be seeded alone or with slow-developing or sprigged grasses and legumes for rapid initial soil protection. Grows 18 in to 24 in high.	0–4000	40+	80
Paspalum conjugatum	Hilograss	Native to Dutch Guiana. Grows 12 in to 24 in tall. Tolerant of shade, drought, wet, and poor soil conditions. Mat is only moderately dense, therefore most effective for erosion control when combined with legumes. Grows with most legumes. Propagated by seed or sprigs. Plant sprigs 3 ft by 3 ft or closer.	0–2500	35+	20
Paspalum hieronymii	Paspalum 'Tropic Lalo'	Native to Brazil. Fast-spreading after establishment. Grows 12 in to 24 in high. Fairly low-maintenance, dense cover. Tolerant of traffic. Effective in cushioning the harshness of A'a lava and other rocky soils, thus easing traffic. Combines with most legumes. Propagated by sprigs; plant 3 ft by 3 ft or closer.	0–4000	40+	—

Table 2. Promising grasses for cover crops. (Cont.)

Scientific Name	Common Name/ Cultivar	Description	Elevation Range (ft)	Rainfall Range (in/yr)	Broadcast Seeding Rate
Paspalum notatum	Bahiagrass 'Pensacola' 'Argentine' 'Paraguay 22' 'Wilmington' 'Paraguay'	Native to South America. Low-growing. Forms a very tight mat. Low-maintenance. Slow-spreading and slow to develop from seed. Tolerant of traffic and shade. Grows about 12 in high. Propagated by seed or sprigs. Plant sprigs 2 ft by 2 ft or closer.	0–4000	40+	40
Pennisetum clandestinum	Kikuyugrass 'Whittet' 'Hosaka' Common kikuyugrass	Native to Central East African highlands. Aggressive, fast-growing. Dense mat 24 in to 30 in high. Combines well with most legumes. 'Whittet' is available commercially as seed; common and 'Hosaka' are propagated by sprigs. Plant sprigs 3 ft by 3 ft apart.	0–7000	35+	10
Stenotaphrum secundatum	Saint augustine-grass	Native to West Indies, Australia, and southern Mexico. Very shade-tolerant. Low-growing and low-maintenance. Grows to 12 in high. Propagated by sprigs; plant 2 ft by 2 ft or closer.	0–3000	40+	—
Triticum aestivum	Wheat 'Florida-301'	Rapid establishment and growth. Seeded for temporary cover either alone or with slow-developing or sprigged materials. Grows best at medium to high elevations but may also be planted during winter months at low elevations. 'Florida-301' grows about 24 in high.	0–4000	40+	100

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Noel P. Kefford, Director and Dean, Cooperative Extension Service, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, Honolulu, Hawaii 96822. An Equal Opportunity Employer providing programs and services to the citizens of Hawaii without regard to race, color, national origin or sex.

RESEARCH EXTENSION SERIES 094–08/88 (2M)