



Akamai Cover Crop Mix: How to establish? Partial Cost Analysis and Its Benefits

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Cover cropping has long been recommended for soil health improvement. Among many types of cover cropping, perennial cover crops could offer further soil health benefits than short-term cover crops that require frequent soil tillage. In the tropical climates of Hawai'i, only few perennial cover crops can establish well, among which, perennial peanuts (*Arachis pintoi*) and 'New Zealand' white clover (*Trifolium repens*) are known to adapt to warmer climates. This research evaluated the use of white clover as a perennial ground cover in Hawai'i.

White clover is a perennial legume, widely adaptable to different soil types and pH but prefers adequate soil moisture. Once established, it is excellent for erosion control, weed suppression, and has efficient N fixing capability. 'New Zealand' white clover can grow vigorously in the tropics due to its heat and moderate drought tolerance, and it is adapted to slug infestations (Ogle and St. John, 2008). Nonetheless, its initial establishment (about 6 months) is a drawback as a cover crop. White clover also has notoriously been reported to be susceptible to different species of plant-parasitic nematodes (Smith and Valenzuela, 2002).

Akamai Cover Crop Mix One approach to overcome the slow establishment of white clover is to plant cover crops that are short-lived but can smother weeds as the white clover establishes. Three cover crops that can potentially be good companion crops with white clover are buckwheat (*Fagopyrum esculentum*), black oat (*Avena strigosa*) and oil radish (*Raphanus sativus*). Although these four cover crops can be good companion cover crops, many leafy green farmers are reluctant to include oil radish as a cover crop due to its potential to attract common *Brassica* pests like imported cabbage worms, diamondback moth, whitefly, and aphids. Thus, we are promoting white clover, black oat and buckwheat as a cover crop mix. We named this combination "Akamai Cover Crop mix" as they have distinct properties as a ground cover, much like a "three-sister-crop" companion planting approach.

Black oat: While white clover can fix nitrogen and enrich soil nutrients, black oat is an annual grass that can produce crop residue with a 34:1 carbon to nitrogen (C: N) ratio (Bauer and Reeves, 1999) and approximately 1.5% tissue N at headset (Gaskell et al., 2011). Black oat possesses N scavenging and C building properties, and also produces allelopathic compounds in its root leachate that inhibit weed growth. Moreover, black oat is resistant to crown rust (*Puccinia coronata* f. sp. *Avenae*) (Carson, 2008), a pathogen that makes use of oat (*Avena sativa*) as cover crop a challenge in Hawai'i. In the tropical climate of Hawai'i, black oats will need 2-3 months of growth to establish but can greatly improve soil physical properties compared to bare ground (Marquez et al., 2022).

Buckwheat: Buckwheat is the fastest and low growing cover crop that produces flush of blooms within 2 weeks of growth, complementing the slow establishment of white clover in a mixed cover cropping system. It generally senesces within 2 months, though it can reseed and regrow voluntarily. Buckwheat produces lots of fine roots, effectively breaking up topsoil and making it more friable (Clark, 2007). Buckwheat can adapt to low soil pH, acts as a phosphorus scavenger, and once its biomass is cut and begins to decompose, it will contribute phosphorus to the soil (Clark, 2007).



How to establish White Clover in an agroecosystem?

- Seed cover crops using seeding rates in Table 1 by broadcasting and raking seeds into the soil. Farmers can sow the seeds during a rainy season or ensure periodic irrigation for white clover to grow over the first 6 months. Here we installed drip irrigation lines that are needed to grow the cash crop (tomato or eggplant). No extra irrigation line was installed other than that needed for the cash crop. Cover crop seeds were sown along both sides of the irrigation lines.

Table 1. Seeding rates, seed costs and time of cover crop growth.

Cover crop mix	Seeding rate (lb/acre)	Cost (\$)	Months to established	Months to senesce
White clover	10	\$80	4-6	perennial
Black oat	20	\$40	2.5	6
Buckwheat	20	\$60	1	2

- Buckwheat will senesce in 2 months. Although it might reseed, as white clover root mats establish, buckwheat growth will be suppressed. During this time, buckwheat provides some shading to protect white clover seedlings (Fig. 1).
- Black oat will take 2-3 months to establish and will grow up to 6 months after planting before it fully senesces, which will provide additional shading for white clover to establish.



Fig. 1. Time to establish a perennial ground cover of white clover using akamai cover crop mix method in a vegetable cropping system (eggplant shown in here) using drip irrigation.

- Initially, cash crops such as trellis tomato (Fig 2a) or eggplant can be intercropped with the cover crops soon after cover crop seeding. Biodegradable paper weed mat (Fig 2b) can be used to protect the tomato or eggplant transplants to keep a distance from the cover crops.

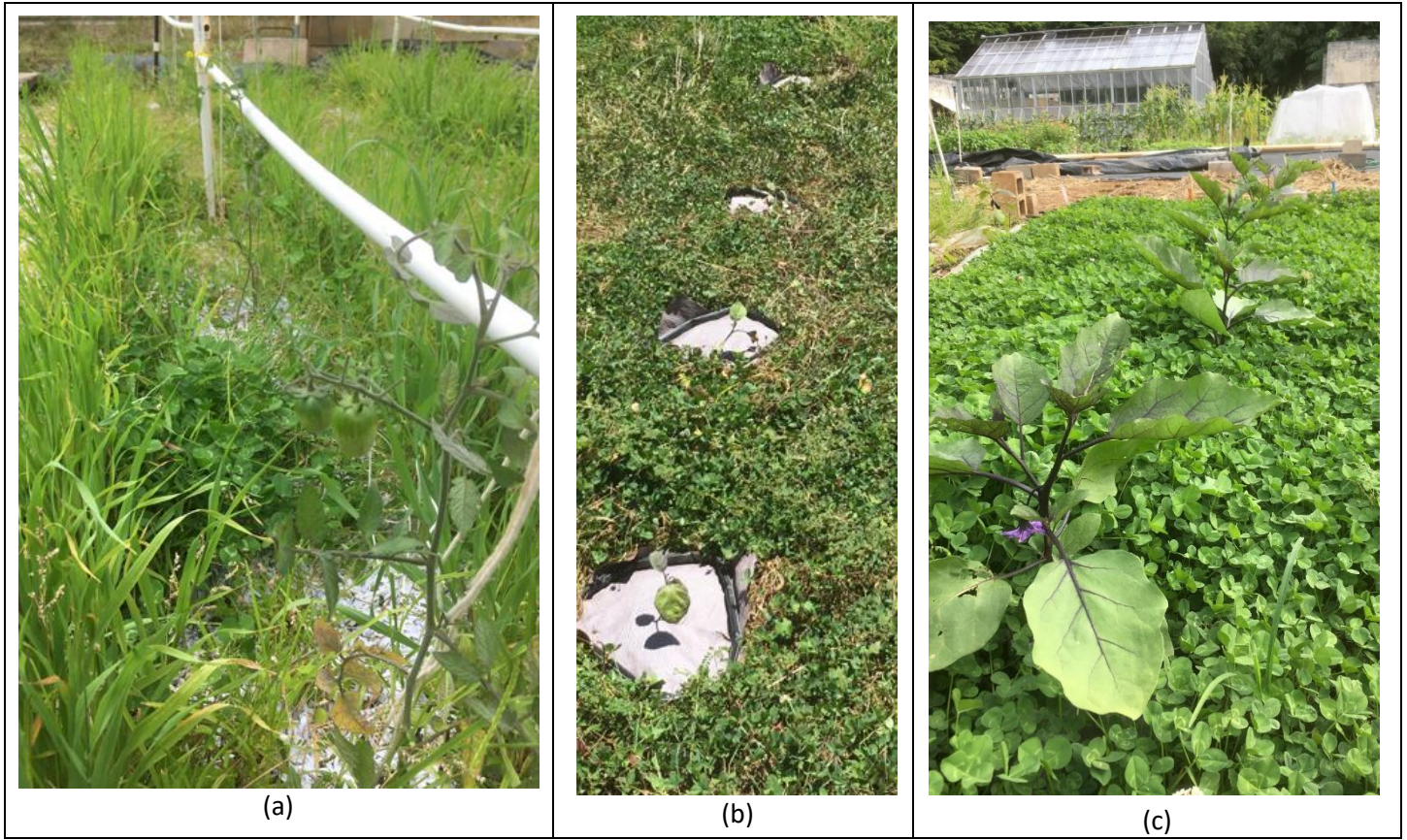


Fig. 2. (a) Tomato seedlings growing on a trellis in between akamai cover crop mix during initial cover crop mix establishment; (b) after tomato crop was terminated, eggplant seedlings were transplanted into the well-established white clover living mulch (about 9 months after cover crop seeding), paper weed mat was used to protect the seedlings from encroaching by white clover; and (c) 11 months after cover crop planting, eggplants were intercropped with white clover.

Case Study

A field trial was conducted at University of Hawai‘i at Mānoa Magoon Teaching Facility to compare weeding time and eggplant growth in 1) akamai cover crop mix (CC), 2) solarization (Sol) for 6 weeks prior to planting, and 3) bare ground (BG) prior to planting. Each treatment plot was 3×15 ft² in size with 5 eggplant plants and replicated in 3 plots. Three-week old eggplant seedlings were transplanted on 14 September 2022. Weeds were monitored on 28 September, 26 October and 9 November 2022 by timing weed removal from each plot as well as % weed cover on 9 November 2022. Eggplant fruits were harvested starting from 2 months after transplanting (Fig. 2c) until December 2022. All data were subjected to analysis of variance using SAS 9.1. and means were separated using Waller-Duncan *k*-ratio (*k*=100) *t*-test wherever appropriate.

Results and Discussion



Fig. 3. Eggplants planted into bare ground (BG), akamai cover crop (CC) and solarization (Sol) plots at Magoon Facility.

As expected, weed pressure was highest in BG throughout the cropping season (Fig. 4). BG was initially covered with weed mat to remain weed free prior to eggplant planting. Weeds were hand weeded by students in Weed Science class (PEPS 481). When weed pressure was too high towards 9 Nov, the students only managed weeds surrounding the eggplant. Thus, additional weed cover data was taken on 9 November. CC only required initial hand weeding with minimal weeding needed in October and November (Fig. 4 B, C). Soil solarization involves covering the soil with a transparent polyethylene film to reach temperatures detrimental to soil organisms and has been found to consistently suppress weed seed banks (Marquez et al., 2014). CC was able to suppress weeds as efficient as Sol (Fig. 4D) and may have long-lasting benefits than Sol that requires this process with each new planting.

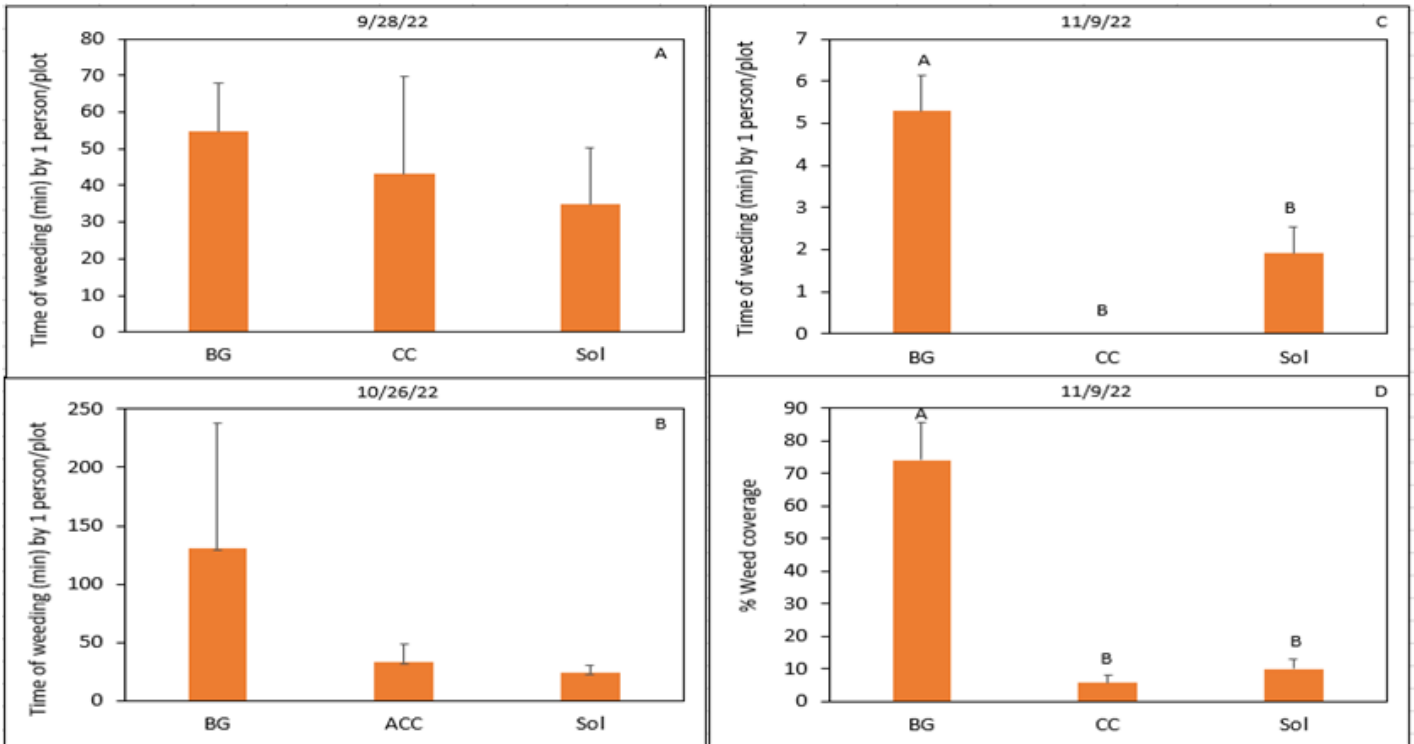


Fig. 4. Effects of ‘Akamai’ cover crops (CC) at 9, 10 and 11 months (A, B, C) after initial cover crop planting compared to bare ground (BG) or solarization (Sol) treatments on weeding time or weed coverage (D) in an eggplant field at Magoon Facility. Means \pm standard error (n=3) followed by different letters are significantly different at each date.

However, eggplant yield in the CC plots were slightly affected by white clover and resulted in slightly lower average yield though not significantly different from the Sol (Fig. 5). Although both CC and Sol had similar low weed pressures, this may have been due to competition by CC. CC produced 2.26 higher yield than the BG. Future research is needed to use a bigger piece of paper weed mat e.g. 2.25 ft² instead of the 1 ft² used to minimize competition.

Nonetheless, this study demonstrates the viability of establishing white clover in agroecosystem with promising weed suppression besides other benefits including improved water infiltration, microbial soil respiration, and soil food web structure measured by nematode structure index (data not presented here).

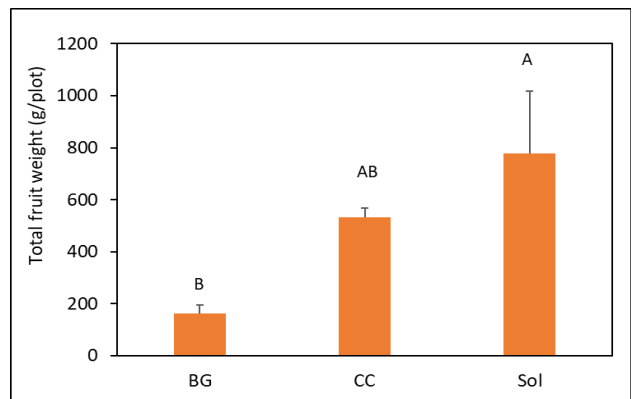


Fig. 5. Eggplant fruit weight harvested from November to December 2022.



Scenarios for Partial Cost Analysis of Akamai Cover Cropping for Eggplant

	Cost	Alternatives
Cover crop seeds	\$180/acre	
Irrigation ²	No additional irrigation besides the irrigation for cash crop.	Cover crop was sown during the rainy season to help initial germination of cover crops.
Weeding	10.7 times less weeding time than BG, based on our case study, it will take 3309 hours/acre to hand weed in BG which is not feasible. Alternative for organic farmers might be using weed mat, which will cost \$120 for a 6x300 ft ² roll.	Akamai cover crop does require intense weeding (1.26 hr / 45 ft ² for this 3-month study) up to 11 months after seeding. Thus, large scale use is not feasible. Once the clover is fully established, no further weeding is possible, i.e. after 11 months, no weeding cost but a barrier is needed to protect the new planting.
Barrier	A biodegradable paper weed barrier (WeedGuard, Gemplers, \$99 / 2x150ft ²) was used in the eggplant case study where 1ft ² was used surrounding an eggplant.	Alternatively, organic farmers can use a weed torch to flame section of white clover prior to eggplant transplanting.
Yield	In this case study, we only create a 1 ft ² barrier surrounding each transplant of eggplant. This led to 35% lower yield than Sol (representing a condition without much weed pressure).	Future research should investigate broadening the barrier for eggplant seedlings to 1.5x1.5 ft ² of no white clover zone for transplanting.

Akamai Cover Cropping for Orchard Crops



Fig. 6. Intercropping white clover with avocado or passion vine (lilikoi) could provide ground cover for weeds and erosion control, while harboring rhizobium that fix nitrogen.

Summary

Companion planting of black oat, buckwheat and white clover offered one approach to establish white clover as a long-term ground cover with multiple benefits to agroecosystems such as erosion prevention, water conservation, carbon storage, nitrogen fixing, soil microbial life harboring, soil food web structuring, and above ground beneficial arthropods sheltering. Once white clover is fully established, it also serves as a weed mat to outcompete weeds. While use of white clover with annual crops such as eggplant or tomato need additional care and labor inputs, this cover crop mix could be transferred to perennial tree crop systems such as avocado, trellis grown lilikoi (Fig 6) without interfering with crop growth. Future experiments could also investigate mowing the top few inches of overgrown white clover periodically to replant a vegetable crop, which can further recycle nutrients from white clover biomass into the soil.

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