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# U.P. Hedrick Award Winner 2011: Alternative Alleyways for Tart Cherry Orchards

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**Abstract**

Current commercial orchard floor practices in the U.S. Intermountain West consist of a grass alleyway and a vegetation-free strip in the tree row. Leguminous cover crops in the alleyway may provide the orchard with additional nitrogen inputs. Alleyway treatments of alfalfa (*Medicago sativa* L.), alfalfa-clover mix (*Trifolium fragiferum* L., and *T. repens* L.), birds-foot trefoil (*Lotus corniculatus* L.), black medic (*Medicago lupulina* L.), hairy vetch (*Vicia villosa* Roth), and a commercial standard grass mix were compared in a mature tart cherry orchard for stand establishment, biomass production, water use, and nitrogen content. A subset of these treatments was also tested in a newly planted tart cherry orchard, and evaluated for stand establishment and weed suppression. Results show that alfalfa, alfalfa-clover mix, and hairy vetch had the best stand establishment at 92.3, 94.6, and 91.5% cover, respectively, comparable to the existing grass alleyway at 91.7%. Alfalfa and alfalfa-clover mix produced the most biomass at 5.28 and 4.53 $T \cdot ha^{-1}$, respectively. However, water use exceeded 5.60 $mm \cdot d^{-1}$ compared to 2.59 $mm \cdot d^{-1}$ for the grass treatment. Birds-foot trefoil did not establish very well and did not suppress weeds significantly. Based on above-ground biomass production and nitrogen content, total potential nitrogen contribution from an alleyway cover of alfalfa would be 143 $kg \cdot ha^{-1}$.

Proper orchard floor management is vital to the health and productivity of fruit trees, with management practices impacting tree growth, pest and disease pressure, fruit yield, and fruit quality. Current recommended orchard management practices consist of a vegetation-free strip in the tree row and a grass cover crop in the alleyway (26). The primary purposes of alleyway cover crops are to stabilize the soil to reduce erosion and minimize dust (5), support wheel traffic, minimize compaction, encourage predator arthropod populations and to suppress weeds.

Soil stabilization in the orchard is particularly critical. In the Intermountain West, orchards are typically planted on sloping sites to provide the appropriate microclimate. Sloped sites improve air drainage and decrease the risk of cold injury to developing flowers and fruit during spring freezes, but are prone to soil erosion especially where alleyways are cultivated. Soil stabilization is also important for dust reduction, as two-spotted spider mite is a common orchard pest that flourishes in dusty conditions (1). Dust can also adversely affect the surface finish of the fruit. Frequent equipment passes are required for insect and disease management, fertility management, vegetation management, pruning, and harvesting, and alleyway cover crops need to stabilize the soil for wheeled machinery. Under conventional management, a tart cherry orchard might require 13 to 30 equipment passes in a season (Table 1). Orchard maintenance and harvest activities are sometimes required during wet conditions when soils are prone to compaction (9).

Effects of alleyway vegetation on both weeds and arthropod pests are also important considerations. One function of vegetation is to suppress weeds so that the alleyway does not become a weed seed source for the tree row, and to prevent weeds from becoming a nuisance problem in orchard management. Piercing and sucking insects, such as lygus bug and stink bug, cause "cat-facing" damage in apples and pears, and have been found to be attracted to leguminous plants in the orchard floor (2). Two-spotted spider

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Table 1. Mowing dates for alleyway cover crop plots in a mature tart cherry orchard at the Kaysville research site during 2010. Mowing was carried out when cover crop bloom approached 10%. Biomass samples were collected at each mowing.

| Cover crops | 20-May | 3-June | 5-July | 7-Sept. |
|---|---|---|---|---|
| Alfalfa | X | | X | X |
| Alfalfa-clover* | X | | X | X |
| Birds-foot Trefoil | | X | X | X |
| Black Medic | | X | X | |
| Hairy Vetch | X | | | |
| Grass | X | | X | X |

*Alfalfa-clover mix (alfalfa 40%, white clover 30%, and strawberry clover 30%)

mites prefer broadleaf plants and care should be taken when growing broadleaf plants in the understory of an orchard. Mowing an orchard during the hot summer months causes mites to move into the tree (1, 13), so timing of mowing also needs to be considered in orchard floor management.

Research in Michigan evaluated the effect of hairy vetch/rye grass mix and a five-species leguminous mix on nutrients, arthropod communities, weed control, and yield in tart cherry. Results indicated that cover crops significantly increased the arthropod abundance and species richness (31). Kuhn and Pedersen (19) compared grass, a grass-perennial clover mix, and an annual legume-grass mix grown in the alleyway of an apple orchard in Denmark, and reported that the annual legume grass alleyway increased fruit yield and fruit size compared to grass and grass-clover combinations. Leguminous mixes that include alfalfa, white clover, and crown vetch have also proved successful in minimizing the impacts that weeds have on a tart cherry orchard in Michigan, USA (29). However, some orchard floor management practices that can suppress weeds and improve soil fertility have also been shown to encourage vertebrate pest populations (33).

The orchard environment presents unique challenges for cover crop selection, particularly in arid climates. Orchard tree pruning and training strategies are specifically designed to maximize light interception by the tree canopy (25), leaving little light for cover crop growth and consequently limiting potential cover crop biomass production (20). Therefore, it is important that any alternative cover crop be adapted to low light conditions. Utah's primary fruit-producing region experiences normal maximum temperatures of 32.2°C in July, and normal minimum January temperatures of -8.3°C. Extreme temperatures can reach as high as 42.2°C and -30°C (23). Average annual precipitation is 33 - 58 cm with as much as 66% of this precipitation in the winter months of November through March (23). Typical orchard soils in Utah range in pH from 7.8 to 8.2 (10), with organic matter content of 0.25 to 1.0% (16). Such low soil organic matter coupled with high calcium carbonate often results in deficiencies of trace elements such as iron and zinc (34). Cover crops that are commonly used in orchards in other temperate fruit growing regions may not be well adapted to the low organic matter alkaline soils, limited water, and seasonal temperature extremes of the Intermountain West.

Despite the potential challenges in selecting appropriate alternative cover crops for inclusion in orchard alleyways, there is a strong incentive to do so. Energy prices continue to rise and fertilizer costs are directly associated with the cost of energy. Alternative orchard floor management practices that include nitrogen-fixing legumes could reduce fertilizer inputs while maintaining or improving tree growth and yield. Increasing soil organic matter with biomass-producing cover crops would also help buffer the negative effects of high soil pH to improve trace element availability. Alternative alleyway cover crops could also have the benefit of conserving limited irrigation water (12, 27).

Alternative alleyway cover crops have not been investigated in the Intermountain West orchard systems and climate. The relative costs and benefits of orchard floor cover crop options need to be assessed in order to improve orchard management systems. Here we report on an initial evaluation of alternative alleyway species for cover crop stand establishment, weed suppression, water use, biomass production, and establishment costs in new and mature tart cherry orchards in the high elevation arid Intermountain West region of the United States.

## Materials and Methods

*Cover crops; Kaysville.* During 2009, candidate cover crops were established in a replicated trial in a mature tart cherry orchard at the Utah Agricultural Experiment Station Kaysville Research Farm, Kaysville, UT (41.01° N latitude, 1333 m elevation). Soil classification is a Kidman fine sandy loam with a pH of 7.5 and 1.5% organic matter. The orchard consisted of 'Montmorency' trees on Mahaleb rootstock planted in 1991 with 3.66 m in-row by 5.5 m between-row tree spacing. Three rows in the orchard were selected for uniform canopy density to provide relatively consistent shade on the orchard floor. Cover crop plots 7.3 m long by 4.5 m wide were established in the drive alleys between herbicide strips. A tank mix of glyphosate (Roundup PowerMAX, Monsanto, St. Louis, MO) and 2,4-D (Weedar64, Nufarm, Dallas, OR) was used to kill the existing grass alleyway, except in the established grass plots. The treated areas were tilled 30 days after herbicide application, leveled, and roller packed prior to seeding the cover crops on 15 Aug. 2009. Cover crops were seeded using a small-plot no-till seeder (Estate Planter Model 304-398, Tye Co., Lockney Texas). The five alternative cover crop treatments were alfalfa (*Medicago sativa* L.; seeding rate of 28 kg·ha$^{-1}$), a mix of alfalfa, strawberry clover (*Trifolium fragiferum* L.), and white clover (*T. repens* L.) in a 4:3:3 ratio ( 16.8 kg·ha$^{-1}$), birds-foot trefoil (*Lotus corniculatus* L.; 28 kg·ha$^{-1}$), black medic (*Medicago lupulina* L.; 16.8 kg·ha$^{-1}$), and hairy vetch (*Vicia villosa* Roth; 67.2 kg·ha$^{-1}$). Each treatment was replicated six times in a randomized complete block design, with blocking by location in the orchard.

The orchard irrigation system consisted of micro emitters (R20, Nelson Irrigation Co., Walla Walla, WA) placed between alternate trees in the tree row. This provided full head-to-head coverage with a water application rate of 0.51 cm·h$^{-1}$. To optimize stand establishment, the irrigation system was run for short daily cycles during the first week after seeding, followed by alternate-day cycles for the following week. Each cycle applied approximately 0.25 cm of water. Orchard irrigation cycles were then returned to normal intervals of 7 days, with 4 cm applied per irrigation.

*Cover crops; Tintic.* In a second trial, cover crops were established in a young tart cherry orchard in Tintic Valley, Utah (39.59 N latitude, 1797 m elevation). Soil classification is a Doyce loam with a soil pH of 7.9 and 2.5% organic matter. 'Montmorency' on Mahaleb rootstock trees were planted in 2008 at 3.66 m by 5.5 m spacing. Cover crop plots, established on 22 Aug. 2009, were 7.3 m wide by 90 m long, comprising two adjacent alleyways for one half the length of the orchard row. The experimental design was a randomized complete block, with four replicate blocks, and blocking by location in the orchard. Seed bed preparation, including herbicide application and tillage, were as described above. Treatments included alfalfa (seeded at 28 kg·ha$^{-1}$), an alfalfa-clover mix as described above (16.8 kg·ha$^{-1}$), hairy vetch (67.2 kg·ha$^{-1}$), and a grass mix of smooth brome (*Bromus inermis* Leyss.), orchard grass (*Dactylis glomerata* L.), and perennial rye (*Lolium perenne* L.) in a ratio of 1:1:1 (30 kg·ha$^{-1}$). The irrigation system in the orchard consisted of micro emitters (R12, Nelson, Walla Walla, WA) placed between alternate trees in the tree row. This provided full head-to-head coverage with a water application rate of 0.51 cm·h$^{-1}$. To optimize stand establishment, the irrigation system was run for short alternate-day cycles

for 1 week. Each cycle applied approximately 0.25 cm of water. Orchard irrigation cycles were then returned to normal intervals of 7 days, with 8 cm applied per irrigation.

*Data collection*. Stand establishment was evaluated 30 days after planting at the Kaysville site. Crop and weed cover were estimated visually for the entire plot. Crop plant density was also determined on two replicate 0.25 $m^2$ quadrats randomly placed within each plot. The following spring, crop and weed cover were visually evaluated in both trials. The Kaysville site was mowed at, or prior to, first bloom for each cover crop (Table 1). Prior to mowing, two replicate 0.25 $m^2$ quadrats were hand harvested, desirable and undesirable vegetation separated, and oven dried to determine biomass. Dried cover crop samples were pooled across replicates and analyzed by combustion for N content (TruSpec C/N, LECO, St. Joseph, Michigan). The Tintic plots were mowed according to standard commercial timing, and no biomass samples were collected.

Dielectric soil moisture sensors (ECH2O model 10HS, Decagon Devices, Pullman, WA) were installed horizontally at a depth of 10 cm in each of three replicate plots at the Kaysville site. The approximate area of influence for this sensor placement is from 5 to 15 cm soil depth. Volumetric water content (VWC) from these sensors was recorded hourly using a data logger (CR 21X, Campbell Scientific, Logan, Utah). The relative water use of each cover crop was determined by measuring the change in soil VWC under each cover. Change in soil VWC was calibrated to crop ET using VWC data from the alfalfa plots, and ET estimates for alfalfa calculated from an automated weather station located just outside the orchard block, within 130 meters of the experimental plots. ET was calculated using the Penman-Monteith equation (3, 24).

*Cost.* Seed cost was acquired from a local farm supply source. Estimates of time and cost that were required to establish cover crops were based on published custom rates (30) .

*Data analysis.* Data were analyzed using GLM procedure of SAS (Version 9.2, SAS Institute Inc., Cary, NC). Data that did not meet the statistical assumptions for normality or constant variance were transformed using log or square-root transformations. Data presented in the results are non-transformed for ease of discussion.

**Table 2.** Stand establishment of alleyway cover crops in a mature tart cherry orchard at the Kaysville farm. Fall stand establishment was rated on 15 Sept. 2009, 30 days after planting. Spring stand establishment was rated on 15 May 2010.

| | | | Fall 2009 | | Spring 2010 | |
|---|---|---|---|---|---|---|
| Treatments | Planting density (seeds/$m^2$) | Plant density (plants/$m^2$) | Crop | Weed | Crop | Weed |
| | | | % cover | | | |
| Alfalfa | 1401 | 709 a[z] | 25.0 a | 4.7 ab | 92.3 ab | 7.0 bc |
| Alfalfa-clover | 1523 | 771 a | 23.3 a | 4.0 b | 94.6 a | 5.3 c |
| Birds-foot Trefoil | 2284 | 805 a | 16.7 b | 4.2 b | 76.6 c | 19.7 a |
| Black Medic | 992 | 803 a | 22.8 a | 1.5 b | 87.3 b | 11.8 b |
| Hairy Vetch | 237 | 61 b | 9.0 c | 8.3 a | 91.5 ab | 8.5 bc |
| Grass | -[y] | - | - | - | 91.7 a | 7.5 c |

[z] Values within a column followed by the same letter are not significantly different at P=0.05.
[y] Grass density and percent cover were not evaluated in the fall, as the plots were established prior to the beginning of the experiment.

## Results and Discussion

*Stand establishment.* At the Kaysville site, cover crop establishment as evaluated 30 days after seeding ranged from 9% to 25% cover, where alfalfa, alfalfa-clover and black medic had the highest percent cover ratings and did not differ significantly (Table 2). Hairy vetch had the lowest cover rating, and birds-foot trefoil cover was intermediate. All of the newly seeded treatments had relatively high initial plant density except for hairy vetch with only 61 plants/$m^2$. By the following spring, stand establishment was highest for the alfalfa, alfalfa-clover, and hairy vetch treatments where cover ratings exceeded 90% and did not differ significantly from the established grass control. The trefoil showed significantly lower cover at 77%. However, it should be noted that the trefoil was not inoculated due to unavailability of the suitable inoculum, and did show some sign of nitrogen deficiency in early growth. Weed cover was inversely proportional to crop cover, indicating that good stand establishment effectively suppressed weed growth.

At the Tintic location, stand establishment evaluated in Spring of 2010 was highest for hairy vetch and alfalfa at 81% and 67%, respectively (Figure 1). Grass had the lowest percent cover, where unlike the Kaysville site, the grass was still being established. The alfalfa and alfalfa-clover treatments were similar in stand establishment. Weed cover data showed no significant differences among treatments.

The Kaysville and Tintic sites represent very different soil, climate and canopy shade conditions. However, alfalfa, the alfalfa-clover mix and hairy vetch all showed good stand establishment at both locations. Sanchez et al. (29) found that alfalfa planted in a mix did well for the first 3 years in orchards and then declined in density. Birds-foot trefoil proved to be difficult to establish in the orchard, but may be a good option once it is established because of its drought tolerance (18).

*Biomass.* Alfalfa and alfalfa-clover treatments showed the greatest amount of total aboveground biomass, whereas trefoil and vetch produced the least (Figure 2). The grass control produced biomass quantities higher than trefoil and hairy vetch but not significantly different from medic. Weed biomass was higher in trefoil than in any other cover crop treatment. Although vetch and trefoil produced similar quantities of biomass over the season, seasonal growth patterns differed significantly. Essentially all of the vetch biomass was produced prior to 20 May, whereas nearly all of the trefoil and medic biomass was produced after 20 May. The vetch biomass residue was not sufficient to suppress weeds, and the vetch plots were very weedy after the first mowing.

The timing of biomass production from the alfalfa and alfalfa-clover treatments was

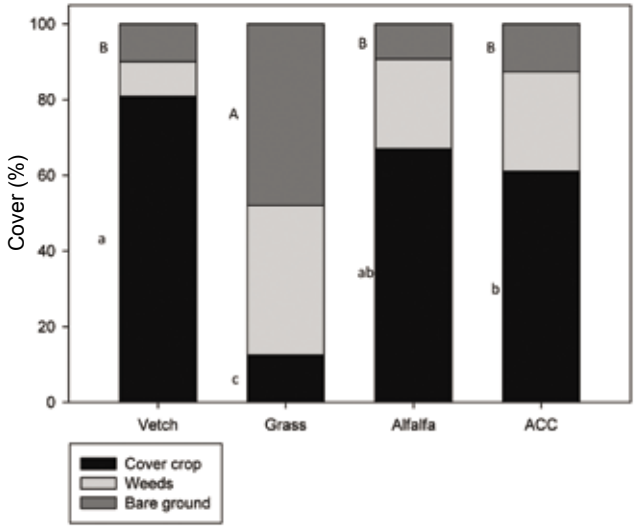



**Fig. 1.** Cover crop stand establishment in alleyways of a young tart cherry orchard at Tintic, UT. Trees were planted spring of 2008. Cover crops were seeded on 22 Aug. 2009, and visually evaluated 18 May 2010. Differences shown at $P \leq 0.05$. (ACC: alfalfa-strawberry clover-white clover).

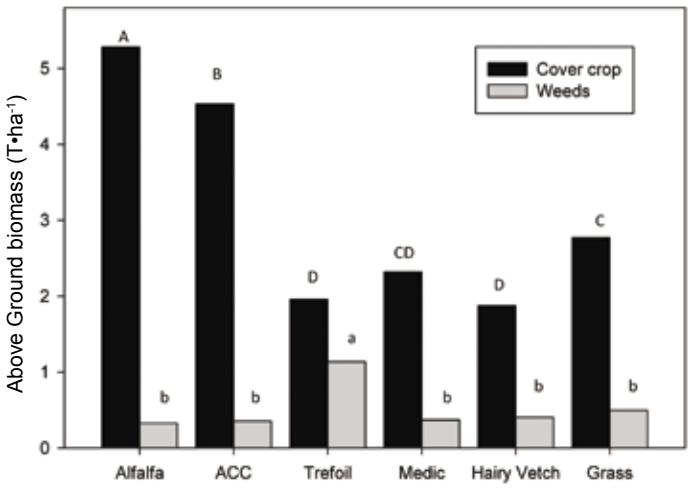



**Fig. 2.** Total above-ground biomass for the 2010 season for alleyway cover crop treatments in a mature tart cherry orchard. Duplicate 0.25 $m^2$ sample areas were harvested from each plot at the time of mowing. Alfalfa, alfalfa-clover, trefoil, and grass were each mowed three times, whereas black medic was mowed twice and hairy vetch was mowed once. Mowing dates are shown in Table 1. Differences shown at $P \leq 0.05$. (ACC: alfalfa-strawberry clover-white clover).

more uniform across the season than the early growing hairy vetch or the late growth of medic and trefoil (Table 1). This would provide more consistent N supply when discharging the mowed biomass into the tree row using the "mow-and-blow" approach (12). Depending on native soil fertility and tree vigor, late-season biomass production could be a disadvantage in a mow-and-blow approach as the timing of N availability has dramatic implications to orchard tree health. High amounts of available nitrogen in the fall can result in excessive late-season vigor that will delay bud set and cold acclimation, leading to risk of winter injury (14). The growth patterns of hairy vetch might be best suited to supplying tree N needs, but would not be adequate for late season weed suppression. Another option would be to discharge the alfalfa clippings into the tree row during the early part of the season, but leave the clippings in the alleyway at later mowing times.

Hairy vetch did not re-grow in Kaysville after the first mowing, but did re-grow in Tintic (data not shown) sufficient for a second mowing. Reseeding of annual legumes such as hairy vetch, may be necessary every year. Although hairy vetch is known to become a weed from reseeding, Sirrine et al. (31) reported that vetch did not seem to persist in an orchard environment. Vetch needs to be allowed to flower sufficiently if reseeding is expected. This could be accomplished by leaving part of the alleyway unmowed, or by delaying mowing until after seed set. However, these strategies may not be compatible with other orchard management needs.

*Nitrogen concentration and contribution.* The N concentration of cover crop biomass was determined on pooled samples preventing statistical analysis, but nonetheless useful for estimating potential N contribution. Hairy vetch produced the highest tissue N concen-

**Table 3.** Cover crop biomass, N concentration and estimated N contribution of alternative alleyway cover crops in a mature tart cherry orchard.

| Treatments | Biomass dry wt. ($Mg \cdot ha^{-1}$) | Nitrogen Concentration (%) | Nitrogen Contribution ($kg \cdot ha^{-1}$) |
|---|---|---|---|
| Alfalfa | 5.28 a | 3.68 | 194 |
| Alfalfa-clover | 4.53 b | 3.95 | 179 |
| Trefoil | 1.95 d | n.d.[z] | n.d. |
| Medic | 2.32 cd | 3.88 | 90 |
| Hairy Vetch | 1.87 d | 5.61 | 105 |
| Grass | 2.77 c | 1.84 | 51 |

[z] Not determined. The quantity of trefoil biomass at a single mowing was minimal, and tissue N concentration was not determined.

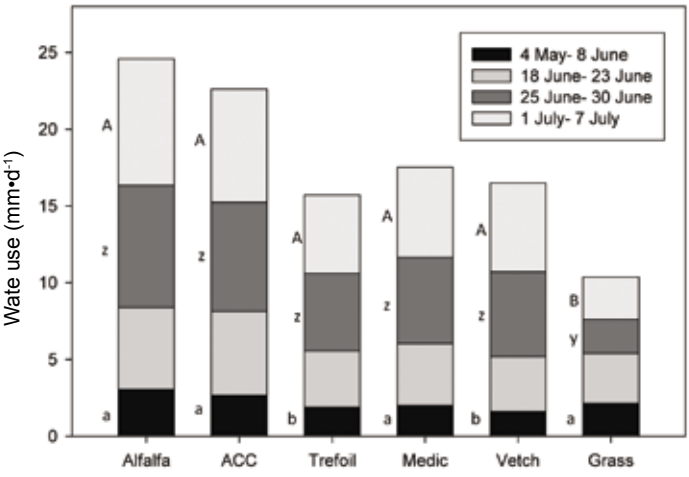



**Fig. 3.** Estimated water use of cover crops from May to July of the year after establishment. Water use was measured over four intervals between irrigation events, and data from the four intervals were analyzed as repeated measures. Results showed a significant treatment x time interaction, where differences during the second time interval were not statistically significant. Treatment differences for the remaining intervals are indicated by letter designations in the figure; $P \leq 0.05$. (ACC: alfalfa-strawberry clover-white clover).

tration at 5.61% (Table 3). Alfalfa-clover and black medic were similar to alfalfa at 3.95 and 3.88% N, respectively. We found a higher tissue N concentration in all of these treatments than are typically reported for these crops. For example, alfalfa has 2.4 to 2.9% N in the aboveground plant biomass (11), compared to 0.93 to 1.81% N in the stem and leaves of birds-foot trefoil (8), 3.12% N for black medic (21), and 4.0 to 4.8% N for hairy vetch (15, 17). White clover that was used in the mix typically has 3.1 to 3.8% N in the plant tissue (4, 21). The higher tissue N concentration reported here may have been due to slower growth rates in the shaded orchard environment.

Typically, a mature tart cherry orchard needs between 140 and 226 kg·ha$^{-1}$ of N per year (14, 32). Based on the aboveground biomass and N concentrations reported here, alfalfa would provide 143 kg·ha$^{-1}$ N using a mow-and-blow approach to redistributing the biomass to the tree row. Not all of the mow-and-blow nitrogen will make it to the orchard tree, with up to 50% loss due to volatilization. This loss of nitrogen can be reduced significantly if the plant material is incorporated into the soil (28). However, N contributions from alleyway legumes are not limited to aboveground biomass. Duback and Russelle (7) report that a significant portion of nitrogen is released by decaying alfalfa roots. We found similar apparent interactions where peach tree growth under limited N conditions was much greater with a trefoil alleyway than with grass (27).

*Water use.* Crop water use, as estimated by change in VWC from 5 to 15 cm soil depth, showed a significant treatment × time interaction (Figure 3), where treatment differences were not significant during the second irrigation interval (18 June to 23 June). During the remaining irrigation intervals, crop water use was generally correlated with biomass production, except in the case of the grass control. Grass plots produced an average of 3.3 ton·ha$^{-1}$ biomass while showing the least amount of soil moisture depletion, suggesting more efficient water use in biomass production. Alfalfa and alfalfa-clover used the highest amount of water (>150% more than the grass control) but both produced the greatest amount of biomass. By contrast, trefoil plots had the least amount of crop biomass, but used more water than grass, partly due to the high amount of weedy biomass present. In dry climates with limited available water, the additional water requirements would have to be weighed carefully against the biomass and N contributions. Long-term improvements in soil quality, water infiltration and retention,

**Table 4.** Estimated costs for establishment year management (field preparation, seeding, and mowing) of alleyway cover crops. Seed prices were based on local sources, and management costs were from published custom rates (30).

| Treatments | Total costs ($/ha) | Relative to grass (%) |
|---|---|---|
| Alfalfa | 284 | 107 |
| Alfalfa-clover | 214 | 36 |
| Birds-foot Trefoil | 305 | 127 |
| Black Medic | 173 | (5) |
| Hairy Vetch | 375 | 197 |
| Grass | 178 | 100 |

as a result of increased carbon input also need to be taken into account when weighing the costs and benefits of such alternative systems.

*Cost.* Establishment and management cost differed by treatment. Hairy vetch was the most expensive treatment, whereas grass and black medic had the lowest costs largely due to seed costs (Table 4). Birds-foot trefoil was the second most expensive to establish, primarily due to higher seed costs resulting from limited availability. Alfalfa seed was from a pasture type and the price was $4.41 more per kg than the conventional hay type alfalfa typically available in the region. The alfalfa-clover mix and black medic were closer in price to the estimated cost of re-establishing a grass alleyway (Table 4). Cost of establishing these different legume species does not take into account that they may need to be reseeded if stands diminish over time, as was previously reported (29, 31).

*Implementation.* Commercial implementation of a leguminous alleyway would require some adaptation on the part of the grower, including equipment, fertility and insect management. To maximize benefits of a legume alleyway, biomass would need to be discharged into the tree row and potentially incorporated into the soil to minimize nitrogen volatilization. Growers would need to purchase or modify seeding and mowing equipment, and possibly invest in in-row cultivation equipment. Currently, none of the commercial orchard mowing equipment is designed to discharge biomass into the tree row. There might also be times during the season when it would be beneficial to leave the biomass in the alleyway to reduce the amount of nitrogen available to the fruit trees late in the season. This may require different equipment, or the ability to modify biomass discharge. Growers would also need guidelines as to when it would be best to discharge leguminous biomass into the tree row, or leave it in the alleyway. In addition to nitrogen release, recommendations for timing of mowing, and where to discharge the biomass need to account for effects on arthropod, microbial, and vertebrate pest populations. Mulching plant biomass in the tree row has been shown to increase the likelihood of vole damage and *Phytophothora* root rot (22). In the arid climate of the Intermountain West, root rot might be less of an issue, but vole damage is a continual concern.

Although alternative cover crops could introduce more nitrogen into the orchard, phosphorus and potassium are important requirements for legume crop growth and may need to be supplemented to maintain adequate biomass production (6). Orchard traffic seemed to impact negatively on all of the cover crops but most especially hairy vetch. Wheel tracks were very evident in the Tintic planting where standard orchard management was implemented. In Kaysville, traffic damage was less evident but this may be due to smaller equipment and fewer maintenance passes used in this relatively small research orchard. Stand density biomass production and cover crop longevity would likely be less in the wheel track areas of the alleyway.

"Cat-facing" insects, lygus and stink bugs, were not evaluated but have been shown to be more prevalent in legume crops. Research has shown an increase in "cat-facing" insects in apples when neighboring alfalfa fields are harvested (2). This may not be a difficult issue in cherries because "cat-facing" insects do not cause economic damage. However, in apple or peach plantings, special consideration would need to be taken in timing of mowing as well as pest management practices.

## Conclusion

Leguminous cover crops could reduce the amounts of nitrogen fertilizer required for orchard systems. For total nitrogen production, alfalfa and alfalfa-clover mix showed the greatest promise in terms of stand establishment and biomass yields, even under the dense canopy of a mature tart cherry orchard. This in-orchard N production comes at a cost of increased irrigation water use, higher establishment and management costs, and the potential to attract undesirable arthropod pests. However, the resulting increase in soil organic matter and nitrogen addition to the orchard may off-set these added costs, particularly under organic management constraints. Alternative orchard floor management strategies should improve orchard sustainability by reducing inputs, lessening adverse environmental impacts, and providing options for organic and conventional growers, while maintaining or improving yields and fruit quality.

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## Efficacy, rate and timing of applications of abscisic acid to enhance fruit anthocyanin contents in 'Cabernet Sauvignon' grapes

The effects of abscisic acid (ABA) on fruit anthocyanin contents was studied on ‘Cabernet Sauvignon’ grapes in the San Joaquin Valley, California. To identify the most effective rates and timing of ABA application, grape clusters on mature vines were sprayed with 150 – 1,200 mg $l^{-1}$ ABA at various stages of berry softening (BS) and berry colouring (BC) between 2005 – 2009. In addition, in 2007, ABA was applied at 600 mg $l^{-1}$ to leaves alone, or to only one grape cluster per shoot, while the other grape cluster on the same shoot was left untreated. ABA at 300 – 600 mg $l^{-1}$ significantly enhanced fruit anthocyanin contents by approx. 20 – 85% in each of the years examined. The application of ABA at 300 – 600 mg $l^{-1}$ at between 80% BC (BC80) and 10 d after 100% BC (BC100) was more effective than earlier applications. Double applications of ABA, once at BC80 plus an earlier application, did not result in any increase in fruit anthocyanin contents compared to a single application at BC80. When applied only to leaves, or to the adjacent grape cluster, ABA at 600 mg $l^{-1}$ did not affect the anthocyanin contents of the untreated grape clusters. Vegetative growth and fruit yield were not affected by ABA. Berry fresh weight, total soluble solids contents, pH, and titratable acidity were only marginally influenced by the ABA treatments. This study demonstrated the potential of ABA to enhance the anthocyanin contents of grapes when applied directly to the berries, while having little or no influence on overall grapevine performance. Paraphrased from: S. Gu, S. Jacobs and G. Du, 2011. The Journal of Horticultural Science and Biotechnology 86(5): 505-510.