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Benefits of Cover Cropping Systems in Walnut Orchards as Sustainable Agricultural Practice

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Abstract

In recent years, walnut orchards implemented cover crops in between rows to improve soil's quality, lessen soil's erosion, increase organic matter, manage nutrient movement and availability, enhance water retention, and expand microbe, insect, and flora diversity. Commonly selected cover crops in California are from families Poaceae, Brassicaceae, and Fabaceae. Considerations should be made when choosing a particular cover crop mixture to enhance multiple benefits and improve sustainable practices in orchard settings. An experiment was conducted in a walnut orchard to compare functionality and benefits of three systems multi-crop, monocrop, and no vegetation cover crop system. The following components were evaluated: cover crop and weed biomass, cover crop species field distribution, ability to provide better coverage, and weed suppression properties. Statistical analysis was conducted using one-way ANOVA and post-hoc Tukey test. Brassica mixture, clover, and grasses showed highest presence in field conditions and excellent weed competition attributes, while peas and faba beans had low presence and did not compete well growing in a mixture with other cover crops. Multi-crop treatment demonstrated dry and wet biomass as well as greatest weed suppression. Recommendations include carefully considering current practice in walnut orchards to seasonally include vegetation cover rather than bare soil, and to choose multi-crop cover rather than monocrop. Implementation of multi-crop species as a sustainable practice would increase soil's quality, improve biological management through rise of natural beneficial predators, and enhance integrated pest management methods.

Introduction

Cover cropping has become more widely adopted by farmers as its various benefits have been validated with the passage of time and attested through research and adaptation of sustainable agricultural practices (Ingels et al., 1998). Conventional production orchards have been typified by a lack of tolerance for anything other than a single crop grown over the course of decades, which makes it difficult to consider cover crop as a standard practice. Although cover

crops have been implemented in orchards since the early 20th century, the development of fertilizers and pesticides in the 1940s and 1950s decreased their presence (Grant, 2006). With a more sustainable purpose, cover crops in orchards became more frequently used in the last 40 years (Ingels et al., 1998). The most common cover crops applied in walnut orchards are grasses, brassica plants, and legumes.

English walnuts (*Juglans regia*) from the family Juglandaceae are the most common commercially produced nuts (DiTomaso & Healy, 2007). English walnuts were introduced in California in the 1770s, though the first walnut orchard was planted in San Diego in 1843. Their origin can be traced back to Eastern Europe, Central Asia, and the Persian region (Tufts et al., 1946). California is a major walnut producer and international exporter (USDA NASS, 2019). In 2019, the USA was the second largest walnut producer in the world, producing 592,390 metric tons of walnuts on 147,710 hectares (FAOSTAT, 2019).

The most utilized cover crops are grasses (Poaceae) because these plants have several mechanisms to enhance soil quality and prevent water loss (Van Sambeek, 2017). Additionally, grasses are hardy plants that can withstand drought or water scarcity. Grass cover crops include cereal crops that are fast growing, can tolerate freezing temperatures, are strong weed competitors, and are compatible in a mix with other broadleaf cover crops (Brennan and Smith, 2005). Popular grass cover crop selections include ryegrass (*Lolium sp.*) and tall fescue (*Festuca arundinacea*) that can serve as a forage (DiTomaso & Healy, 2007; Ingels et al., 1998). Other applied cover crops are brassicas (Brassicaceae) and leguminous plants (Fabaceae). Brassicas can rapidly increase biomass by producing deep taproots, which enhance their weed suppression abilities and alleviate soil compaction (Brennan and Smith, 2005; Boydston & Al-Khatib, 2005). Deep root systems can extract nitrogen from deeper and shallow soil strata, therefore, enhancing the nutrient cycling process (Ugrenovic et al., 2019). In the spring, brassicas stipulate pollination, provide a diverse habitat that attracts pollinators and other beneficial insects, and can assist with honey production in young orchards during the first few years (Ellis & Barbercheck, 2014). Studies have elucidated additional beneficial characteristics such as biofumigation and allelopathic properties (Ugrenovic et al., 2019). Legumes have a major role in the process of biological nitrogen fixation enhancing available forms of ammonia and nitrates that is crucial for the nutrient cycle and plants' healthy growth and development (Peoples & Craswell, 1992). This sustainable practice increases soil's fertility and reduces fertilizer requirements over time (Goh et al., 2008). The use of a variety of grasses, brassicas, and leguminous plants as a cover crop mix in appropriate ratios can furthermore provide multiple benefits in an orchard environment. Overall, the purpose of employing cover crops in orchards is to lessen economic costs and increase benefits such as crop yield, healthy growth, and development.

The cover crops considered and applied for this study were based on the desire to gain improvements from each plant family in the walnut orchard. The multi-crops selected were a mixture of oats, barley, triticale (water retention, crop companion), mustards (weed suppression, pollination), bell beans, peas, and clover (nitrogen amendment). Single cover crop consisted of bell beans attributing to the ability to provide nitrogen. There were several objectives for the utilization of cover crops in the walnut orchard: 1) to compare the cover crop treatments (multi-crop and monocrop) with the no vegetation control group in the walnut orchard, 2) to assess the field distribution of the different crop species planted to determine which system would provide greater cover and weed suppression in the walnut orchard, and 3) to quantify which system had the greater biomass. We hypothesized that the multi-crop treatment would provide the greatest weed suppression and yield the largest biomass compared to the monocrop treatment, and that the monocrop treatment would serve as a better weed competitor compared to the no vegetation control group.

Literature Review

Walnut Benefits

Walnuts are a highly valued commodity due to their nutritional importance and health benefits (Fatima et al., 2018). Nuts are rich in fats and proteins, 65 and 15 percent respectively (Sen & Karadeniz, 2015), as well as in polyphenols and organic compounds that contain antioxidant properties, inhibit oxidation, and consequently decrease atherosclerosis (Fatima et al., 2018). Other studies demonstrate walnuts' health benefits such as managing diabetes, lowering inflammation of blood vessels, and lowering blood pressure for an overall improvement of the cardiovascular system (Blomhoff et al., 2006; Yang et al., 2009).

In the process of growth and development, the walnut shell and husk protect the nut. After the harvest, both shell and husk are discarded as a waste product. However, new studies are showing a different potential using walnut husk, shells, and leaves as an alternative material to dye clothing and hair. Juglone represents the main ingredient that pro-

vides a strong color for cotton, viscose, and wool materials (Bukhari et al., 2017). This sustainable and ecologically aware practice has a wider range of applications from dyeing textile materials to developing hair and cosmetic products.

Cover Crop Benefits

Family Poaceae

Characteristics of grasses include large seed production and growth in semi-shaded conditions, which allows vegetation coverage to be present in walnut orchards throughout the year (Grant, 2006). Grass cover crops can develop long fibrous roots, break compacted soil, prevent erosion, and absorb nitrogen and potassium from deeper strata (Muhandiram et al., 2020). Removal of winter crops such as winter rye and wheat in the fall can deplete nitrogen from walnut orchard, on average 78.5 kilograms of nitrogen per hectare. Sustainable practices to mitigate nitrogen loss include harvesting and leaving grass in the field as a mulch, decomposable organic material, and companion planting with legume plants (Van Sambeek, 2017; Granatstein et al., 2014). A multispecies cover crop compared to a single species cover crop has more benefits especially in increasing microbe diversity and maintaining healthy soil (Van Sambeek, 2017; Finney et al., 2017).

Grasses such as narrow-leaved monocots have good weed competition properties (Grant, 2006). One study found that grasses showed better or equal weed suppression compared to herbicide usage when tested in greenhouse and field conditions. Red fescue was more competitive in greenhouse conditions compared to perennial ryegrass with other weeds. However, in field conditions both grass species demonstrated equal effectiveness in combating weeds in orchard settings compared to chemical management (Tworkoski & Glenn, 2012). It would be advantageous to use the weed suppressive abilities of grasses and reduce chemical usage for a heathier and more sustainable orchard management.

Family Brassicaceae

Brassicas, most commonly mustards and rapeseeds, form basal rosette, have erect growth, higher biomass, and large number of flowers (DiTomaso and Healy, 2007). Mustards have a long tradition as cover crops in walnut orchards and are typically applied for pollination purposes, enrichment of pollinators, mainly bees and butterflies, and beneficial insect species like parasitic wasps, green lacewings, and ground predatory beetles (Redhead et al., 2020). Increasing insect diversity can enrich the orchard's ecosystem and enhance biological management as one of its integrated pest management tactics (Ellis and Barbercheck, 2014; Redhead et al., 2020).

In California, a specific program known as "Beewhere" has been applied to keep track of beekeepers' hives within orchards. This system was developed in 2017 with the goal of creating an awareness of beekeepers and pest control applicators' role in orchards as insecticides are applied more frequently in the spring. Furthermore, the County Agricultural Commissioner's office temporarily prevents spring usage of neonicotinoids, nerve system acting insecticides, as they are more harmful to insect pollinators (BeeWhere-California, 2021). Established at the state level, this process has granted additional protection for insect pollinators and beneficial predators.

Mustard species implemented as cover crops in orchards can rapidly increase biomass and cover up to 80 percent of soil (Ugrenovic et al., 2019). As such, they represent excellent weed competitors (Brennan & Smith, 2005; Boydston & Al-Khatib, 2005). Brassicas are known for their biofumigant properties, i.e., the ability to release phytotoxic substances into a soil, mainly glucosinolates, which then convert into isothiocyanates and decrease soil pathogens, nematodes (Ugrenovic et al., 2019), weed seed germination and growth of other weed species (Al-Khatib et al., 1997). Al-Khatib's team (1997) conducted an experiment testing the biofumigant and allelopathic properties of mustard, rye, and wheat species as cover crops before planting a pea crop. After harvesting the cover crops, peas were planted as a regular crop in the spring. Crop and weed biomass were compared one month after planting the principal crop. This study confirmed that the pea crop had the highest yield and lowest weed presence when mustards, more specifically white mustard and rapeseed, were used as cover crops. This demonstrated the potential of applying brassicas as cover crops that would suppress weed competitors. Other studies have supported the efficacy of rapeseed and mustards species exhibiting these characteristics whether used as cover crops or applied in soil as a manure amendment (Van Sambeek, 2017; Ugrenovic et al., 2019). These practices are opening doors to lowering the amount of pesticide usage and implementing sustainable integrated pest management practices in orchard settings.

Family Fabaceae

Legumes are short-lived crops that can withstand harsh winter weather and extra wet spring seasons with the main role to provide nitrogen for the principal crop via the pro-

cess of biological nitrogen fixation (Peoples & Craswell, 1992; Perrone et al., 2020). Legume plants form a symbiotic relationship with *Rhizobia,* a soil bacteria that forms nodules on plant's roots (Perrone et al., 2020). Nitrogen is restored back to the soil decreasing the need for additional fertilizer application (Goh et al., 2008). A higher amount of nitrogen can be provided to walnut trees via direct planting of legumes, compared to mowing and leaving plant residue, to decompose (Grant, 2006; Anderson et al., 2006). Walnut's nitrogen demand starts increasing in late March and beginning of April making legumes a good option to lessen its impact (Anderson et al., 2006).

In a study conducted by a Japanese team, five different legume plants were tested for their biomass, nodule formation and nitrogen fixation capacity using the acetylene reduction activity (ARA) method (Rutto et al., 2003). The scientists used three vetch species: airy, narrow leaf (*Vicia villosa* and *V. angustifolia*) and Asian milk vetch (*Astragalus sinicus*), and two clover species: red and white (*Trifolium pratense* and *T. repens*). Wet and dry biomass were measured by comparing the shoots and roots of the five species. Red clover and hairy vetch recorded the highest biomass, both wet and dry weight, while narrow leaf vetch showed the lowest results. At harvest, entire plants were removed from the soil, roots separated from the plants, nodules separated from the roots and partitioned into five different groups depending on the size from the smallest to largest. Although Asian milk vetch demonstrated the largest number of nodules, they were small compared to red clover's nodules that were the largest of them all. After the flowering stage, all plants revealed a decrease in nodule formation. The ARA method showed variations in nitrogen production by all five species, where white clover showed a significant increase in March and April compared to other species (Rutto et al., 2003). This demonstrates the potential usage of clovers in walnut orchards when it is the most required by the trees. Aside from nutrient amendment, legume plants are good in weed suppression and preventing soil erosion (Thorup-Kristensen et al., 2003; Grant, 2006). As seen in a previous study, both red clover and hairy vetch demonstrated good soil coverage, prevention of soil erosion and weed suppression properties (Rutto et al., 2003). Another study confirmed the efficacy of white clover and hairy vetch as plants that can be highly competitive with weeds while developing smaller biomass (Van Sambeek, 2017). Faba beans can represent soil's nitrogen booster, fixing up to 200 kilograms of nitrogen per hectare (Karkanis et al., 2018). However, studies have shown that faba beans are weak weed competitors and struggle with the influence of abiotic factors. Therefore, faba beans would not be recommended as a monocrop cover crop (Frenda et al., 2013; Karkanis et al., 2018). In comparison, cowpeas, which are good weed competitors, used less water than other legumes when growing, which makes it a good conservative water usage cover crop (Van Sambeek, 2017).

Typical leguminous plants used in California orchards as cover crops are vetches, clovers, peas, and beans that attract pollinators when in bloom and beneficial predators of pests in orchards (Ellis and Barbercheck, 2014). White and strawberry clover legumes often provide vegetation cover in walnut orchards throughout the year. Clovers have the most positive impact on pollinators as they provide an abundance of high-quality pollen and nectar (Van Sambeek, 2017). Nonetheless, mowing is necessary when doing floor sanitation and field management such as tree pruning and removal of navel orangeworm's (NOW) mummy nuts in the fall and early winter (Grant, 2006). NOW is a major economic, severe pest in walnut orchards (Stern et al., 1959). A study conducted by Sibbett and Steenwyk (1993) showed that in years when weeds were left in orchard NOW mummy nuts had less emergence in the spring compared to an orchard floor with no vegetation cover. Having cover crops as vegetation cover can lower the presence of mummy nuts and be seen as an additional sanitation method (Sibbett & Steenwyk, 1993). Careful consideration should be given to current practices in a walnut orchard to determine which benefit can be gained from integrated pest management practices. This can lead to early season mowing or keeping cover crops until early spring.

Cover Crop Disadvantages

The disadvantages to legumes are attracting pests like the stink bugs, leaffooted bugs, and lygus bugs as well as potentially requiring more water for crop growth (Bugg & Waddington, 1994). However, aside from stink bugs that can occasionally feed on immature nuts (Van Sambeek, 2017), these insects are not harmful to walnut trees (Grant et al., 2020) and, as such, can be classified as a non-economic, rare pest category (Stern et al., 1959). According to Stern (1959), pest populations of this category never reach economic threshold as they maintain constantly low population densities, and no management is implemented to remove them from walnut orchards. Cereal and legume crops can serve as a habitat for the root nematode species from the genus *Pratylenchus*; however, they are not showing economical damage to walnut roots (Grant, 2006; Stern

et al., 1959). Although cover crops can capture water from walnut trees, they can increase water holding capacity in the soil (Grant, 2006). Preferably cover crops would be used in the winter months with the expectation that winter rains would decrease the need for additional orchard and cover crop irrigation (Altieri et al., 2018). Water usage by cover crops is less in walnut compared to almond orchards due to greater canopy, higher moisture, and better water preservation (Grant, 2006).

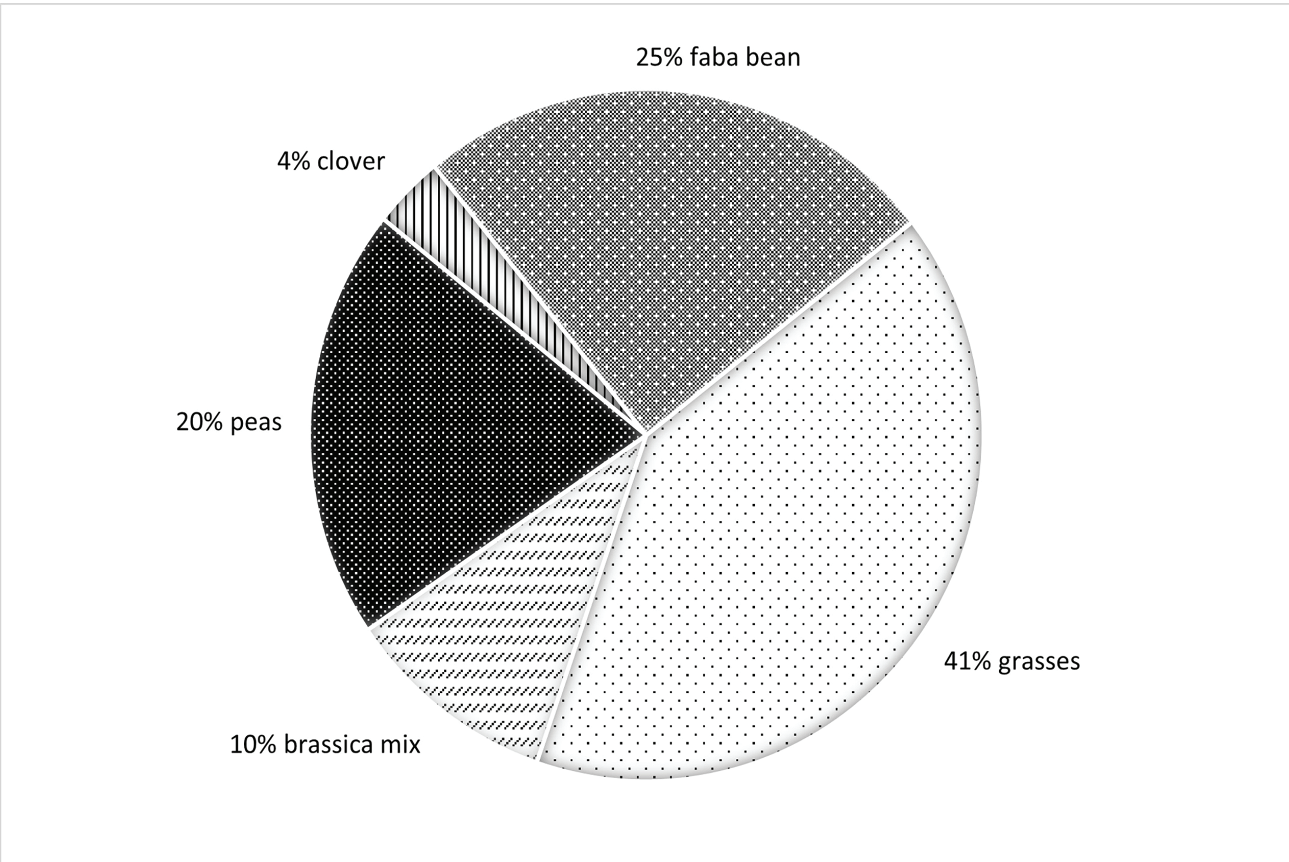
Methods

Location and Treatments

The one-year long experiment was conducted at a walnut orchard in northern Chico, CA (39.798362° N, 121.902541° W). Cover crops were planted with a grain drill in the beginning of November 2019. The two treatments consisted of multi-crop cover and monocrop cover, and the control consisted of no vegetation cover to compare these two systems. Treatments and control were alternated every two rows for planting in between the walnut orchards. The multi-crop treatment, Lockwood Seeds 22.7-kilogram bag of Orchard Mix was sowed into the soil at a rate of 84 kilogram of seeds per hectare. The mix consisted of nine different seed species from the families Poaceae (cayuse oats, UC132 oats, UC937 barley, forerunner triticale), Fabaceae (PK crimson clover, magnus peas, dundale peas, faba beans), and Brassicaceae (W. brassica mix) with a varying percentage distribution based on higher germination rates (Figure 1). For the monocrop cover, faba bean Baglietto Seeds 22.7-kilogram bag was sowed into the soil at a rate of 134 kilogram of seeds per hectare and inoculated with

Figure 1

Percentage of multi-crop seeds of planted species as present in Lockwood Seeds Orchard Mix.



Note. This mixture contained in successive order from greatest to least amount grasses, bell bean, peas, brassica, and clover. This distribution is based on germination rates known for each crop.

N Dure premium inoculant. The multi-crop treatment was not inoculated.

Experiment Setup

The walnut orchard area where the experiment took place included six rows containing two rows for each treatment (multi-crop, monocrop) and control (no vegetation cover). The experimental area was divided into five blocks where square meter transects were placed using a complete randomized design. Rows were 9 meters wide and 280 meters long with each block being 18 meters wide and 56 meters long. There were five transects per row, totaling 30 transects.

Data Collection

During this experiment, the following data was collected: quantitative distribution of crops and weeds per transect during seedling and mature plant stage, crop biomass, and weed biomass. Distribution data was collected on two separate occasions January 20, 2020 and February 29, 2020. On March 7, 2020 final harvest data was collected using 30-centimeter square transects. Crops and weeds were harvested from each transect (subsample) followed by biomass measurement. From field, fresh plant subsamples from each transect were placed on an Ohaus Defender 5000 hybrid scale to collect weight data. Crops and weeds were placed in properly labeled paper bags and moved to a drying oven. After two weeks, dry samples were weighed.

Results

Seed and Crop Distribution

The distribution of the multi-crop mixture, which was sown on November 7, 2019, was examined after sowing to observe how the seed densities affected crop distribution. Two distribution counts were completed after crops had grown considerably, January 20, 2020 and February 29, 2020 respectively (Table 1).

Crop and Weed Density

The multi-crop treatment yielded the greatest density distribution of vegetative cover over weeds in comparison to the monocrop treatment for the months of January and February. In January, the multi-crop and monocrop treatment vegetative cover in comparison to weed coverage was 80 percent and 33 percent of crop, respectively. In February, vegetative cover was 71 percent for multi-crop and 19 percent for monocrop.

Wet and Dry Biomass

The multi-crop treatment yielded the greatest wet biomass when compared to both monocrop treatment and no vegetation control. Multi-crop and monocrop treatments demonstrated greater cover presence than the no vegetation control (Figure 2). The multi-crop cover yielded the greatest dry biomass compared to the other two systems. Dry biomass of the multi-crop and monocrop cover treatments demonstrated similar cover presence over weed presence to that of wet biomass (Figure 3).

ANOVA Analysis

The conducted statistical analysis in this experiment was one-way ANOVA. A post-hoc Tukey test was performed to analyze statistical significance of crop vs weed wet and dry biomass for the multi-crop treatment, monocrop treatment, and the no vegetation control. The data for biomass showed a statistically significant difference between multi-crop treatment and no vegetation control ($p < 0.01$). Conducting the Tukey test only on multi-crop and monocrop treatments showed a statistically significant difference ($p < 0.01$) (Table 2).

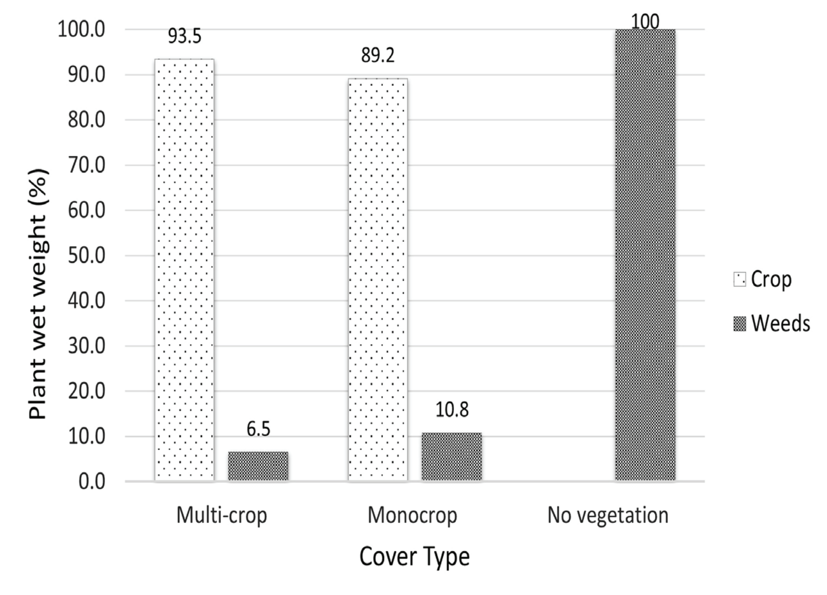
Table 1

Percentage of multi-crop seed distribution at planting, and field crop distribution at two different days after planting (DAP) periods.

Plant Type	Seed Bag Distribution (%)	Crop Distribution 64 DAP (%)	Crop Distribution 104 DAP (%)
Grasses	41	30.83	29.27
Brassicas	10	46.44	42.33
Peas	20	3.85	5.40
Clover	4	17.37	19.88
Faba beans	25	1.51	1.46

Figure 2

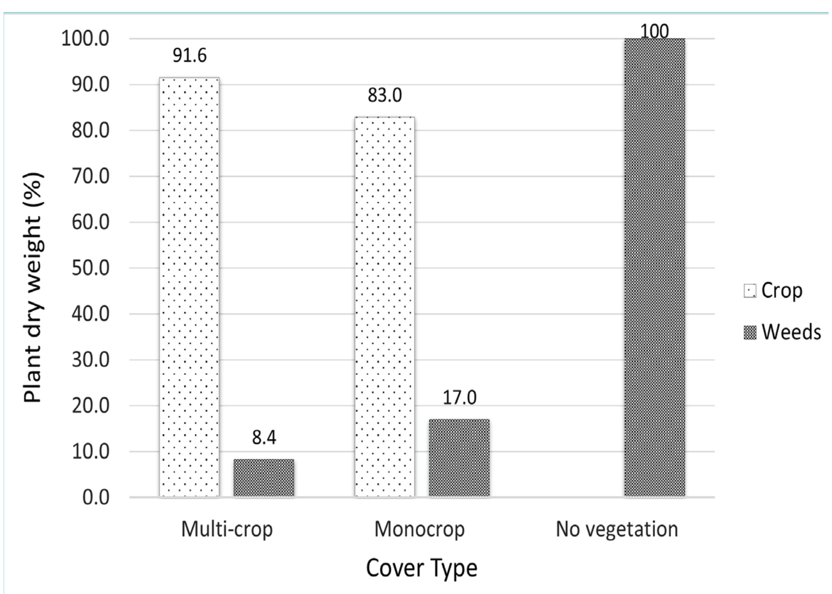
Wet biomass percentage of crops and weeds from each cover crop system collected on March 7, 2020



Note. Distinguishing crop and weed weight. The no vegetation control group was composed solely on weeds while multi-crop and monocrop treatments included both crop and weed plants.

Figure 3

Dry crop and weed weight, collected on March 7, 2020



Note. Presented in three different cover crop systems multi-crop treatment, monocrop treatment, and no vegetation control. Crop and weeds were present in treatment groups while the control group consisted of weeds only.

Table 2

Post-hoc Tukey test p values of wet and dry biomass

Treatment Pair	Wet Biomass	Dry Biomass
multi-crop vs no vegetation	0.004	0.001
multi-crop vs monocrop	0.001	0.001

Note. Comparison is made between treatments and control as well as between both treatments. All statistically significant differences recorded p values less than 0.01.

Discussion

Planted certified seed mixture contained amounts that varied for each type of crop in accordance with germination rates as seen in Table 1. Brassicas and clovers had a low seed planting distribution that significantly increased in field distribution. Although grasses slightly decreased their field distribution after planting, they demonstrated a strong presence and competitiveness when mixed with other crops. Peas and faba beans had a high seed planting distribution that decreased significantly in field conditions, which demonstrated their weak competitiveness with crops and weeds. It was observed that the multi-crop treatment had greater crop coverage and weed suppression than the monocrop treatment without vegetation cover system. This could be due to the variety of the mixture containing species that germinate quick enough to suppress weed growth as confirmed by various case studies (Rutto et al., 2003; Brennan & Smith, 2005; Boydston & Al-Khatib, 2005; Grant, 2006). Even though the monocrop treatment had a lower amount of crop over weed density, the faba beans had greater canopy and height than the weeds.

The multi-crop treatment had the greatest wet and dry crop biomass as seen in Figures 2 & 3. It should be noted that both treatments (multi-crop and monocrop) had greater wet and dry crop biomass than the no vegetation cover system. Having multi-crop coverage in the young walnut orchard provided great weed competition, attraction of beneficial insects, pollinator presence, and overall healthier soil as confirmed by other studies (Grant, 2006; Ellis & Barbercheck, 2014; Van Sambeek, 2017; Finney et al., 2017; Streit et al., 2019). The monocrop cover had similar benefits though the presence of beneficial insects and pollinators was weaker, which could be due to underdeveloped faba bean flowers.

Conclusion

Implementation of multi-crop coverage is the best practice to obtain numerous benefits. The experiment provided supporting evidence for this since the multi-crop treatment was superior in results, followed by the monocrop treatment. The variety of compatible crops in a multi-crop system leads to achieving a combination of benefits that contributes to the health of the soil. Grasses are good crop companions, assist with weed suppression, increase water retention, and improve soil vigor. Brassicas have biofumigation and allelopathic properties, attract pollinators and beneficial predators, and are excellent weed competitors. Legumes provide biological nitrogen fixation and attract pollinators but also potential pests. Depending on the species, some legumes are good weed competitors (clovers) while others are poor weed competitors (faba beans and peas). Faba beans, which are poor weed competitors in early stages, as monocrop will still provide various benefits once more fully developed, such as nitrogen amendment, pollination, and increased biodiversity in walnut orchards. However, choosing clover may be a better option as it provides greater weed suppression. Choice of cover crop will vary depending on the age of the walnut orchard, nonetheless, a form of vegetative cover is more favorable than leaving bare soil conditions. Cover cropping is a sustainable approach towards soil health of walnut orchards, which will establish long-term benefits and support an integrated pest management system. In conclusion, there is much to gain from the use of cover crops, especially in a young walnut orchard where walnuts are not fully yielding, and crops will be grown for various years.

References

Al-Khatib, K., Libbey, C., and Boydston, R. (1997). Weed

suppression with Brassica green manure crops in green pea. *Weed Science*, 439-445.

Altieri, M. A., Farrell, J. G., Hecht, S. B., Liebman, M., Magdoff, F., Murphy, B., Norgaard, R. B., and Sikor, T. O. (2018). Agroecology the science of sustainable agriculture cover cropping and mulching. In *Agroecology* (pp. 219-232). CRC Press.

Anderson, K. K., Grant, J., Weinbaum, S. A., and Pettygrove, S. (2006). *Guide to Efficient Nitrogen Fertilizer Use in Walnut Orchards*. UC ANR. Publication 21623.

BeeWhereCalifornia. (2021). BeeWhere. Retrieved on June 7, 2021 https://beewherecalifornia.com/

Blomhoff, R., Carlsen, M. H., Andersen, L. F., and Jacobs Jr, D. R. (2006). Health benefits of nuts: Potential role of antioxidants. *British Journal of Nutrition, 96*(S2), S52–60.

Boydston, R. A., and Al-Khatib, K. 2005. Utilizing brassica cover crops for weed suppression in annual cropping systems. In H. P. Singh, D. R. Batish and R. K. Kohli (eds.) *Handbook of sustainable weed management* (pp. 77–94). Binghamton, NY: Haworth Press.

Brennan, E. B., and Smith, R. F. (2005). Winter cover crop growth and weed suppression on the central coast of California. *Weed Technology, 119*(4), 1017–1024.

Bugg, R. L., and Waddington, C. (1994). Using cover crops to manage arthropod pests of orchards: A review. *Agriculture, Ecosystems & Environment, 50*(1), 11-28.

Bukhari, M. N., Shabbir, M., Rather, L. J., Shahid, M., Singh, U., Khan, M. A., and Mohammad, F. (2017). Dyeing studies and fastness properties of brown Naphthoquinone Colorant extracted from Juglans Regia L on natural protein fiber using different metal salt mordants. *Textiles and Clothing Sustainability, 3*(1), 1-9.

DiTomaso, J. M., and Healy, E. M. (2007). *Weeds of California and Other Western States Vol 1 & 2*. UC ANR, Publication 3488.

Ellis, K. E. and Barbercheck, M. E. (2014). Management of overwintering cover crops influences floral resources and visitation by native bees. *Environmental Entomology, 44*(4), 999-1010.

Fatima, T., Showkat, U., and Hussain, S. Z. (2018). Nutritional and health benefits of walnuts. *Journal of Pharmacognosy and Phytochemistry, 7*(2), 1269.

FAOSTAT. (2019). *Walnut in shell production in 2019, crops/regions/world list/production quantity pick lists*. UN Food and Agriculture Organization, Corporate Statistical Database (FAOSTAT). Retrieved on May 12, 2021 http://www.fao.org/faostat/en/#data/QC

Finney, D. M., White, C. M. and Kaye, J. P. (2017). Biomass production and carbon/nitrogen ratio influence ecosystem services from cover crop mixtures. *Agronomy Journal, 108*(1), 39-52.

Frenda, A. S., Ruisi, P., Saia, S., Frangipane, B., Di Miceli, G., Amato, G., and Giambalvo, D. (2013). The critical period of weed control in faba bean and chickpea in Mediterranean areas. *Weed science, 61*(3), 452-459.

Goh, K. M., Ridgen, G. E., and Daly, M. J. (2008). Understorey biomass production and biological nitrogen fixation in an organic apple orchard in Canterbury, New Zealand. *Communications in Soil Science and Plant Analysis, 26*(19-20), 3261-3273.

Granatstein D., Andrews P., and Groff A. (2014). Productivity, economics, and fruit and soil quality of weed management systems in commercial organic orchards in Washington State, USA. *Organic Agriculture, 4*(3), 197–207.

Grant, J. (2006). *Cover Crops for Walnut Orchards*. UC ANR, Publication 21627.

Grant, J. A., Symmes, E. J., Baldwin, R. A., Fichtner, E. J., Roncoroni, J. A., Westerdahl, B. B., Adaskaveg, J. E., Bostock, R. M., Browne, G. T., Buchner, R.P., Coates, W. W., Elkins R. B., Gubler, W. D., Hanson, B., Hasey, J. K., Hembree, K. J., Michailides, T. J., Seybold, S. J., Van Steenwyk, R. A., & Westphal, A. (2020). *UC IPM Pest Management Guidelines: Walnut*. UC ANR, Publication 3471.

Ingels, C. A., Bugg, R. L., McGourty, G. T., and Christensen, L. P. (1998). *Cover Cropping in Vineyards, A Grower's Handbook*. UC ANR, Publication 3338.

Karkanis, A., Ntatsi, G., Lepse, L., Fernández, J. A., Vågen, I. M., Rewald, B., Alsiņa, I., Kronberga, A., Balliu, A., Olle, M. and Bodner, G. (2018). Faba bean cultivation–revealing novel managing practices for more sustainable and competitive European cropping systems. *Frontiers in Plant Science, 9,* 1115.

Muhandiram, N. P., Humphreys, M. W., Fychan, R., Davies, J. W., Sanderson, R., and Marley, C. L. (2020). Do agricultural grasses bred for improved root systems provide resilience to machinery-derived soil compaction? *Food and Energy Security, 9*(3), 227.

Peoples, M. B., and Craswell, E. T. (1992). Biological nitrogen fixation: Investments, expectations and actual contributions to agriculture. *Plant and Soil, 141*(1), 13-39.

Perrone, S., Grossman, J., Liebman, A., Sooksa-nguan, T., and Guthnecht, J. (2020). Nitrogen fixation and productivity of winter annual legume cover crops in upper Midwest organic cropping systems. *Nutrient Cycling in Agroecosystems, 117*(1), 61–76.

Redhead, J. W., Powney, G. D., Woodcock, B. A., and Pywell, R. F. (2020). Effects of future agricultural change scenarios on beneficial insects. *Journal of Environmental Management, 265*, 110550.

Rutto, K. L., Mizutani, F., Moon, D. G., and Cho, Y. S. (2003). Nitrogen fixation and N-balance studies of candidate legume cover crops for use in orchards. *Journal of the Japanese Society of Agricultural Technology Management, 10*(1), 29-35.

Sen, S. M., and Karadeniz, T. (2015). The nutritional value of walnut. *Journal of Hygienic Engineering and Design, 11*(18), 68-71.

Sibbett, G. and Van Steenwyk, R. 1993. Shredding "mummy" walnuts is key to destroying Navel Orangeworm in winter. *California Agriculture, 47*(5), 26-28.

Stern, V. M., Smith, R. F., van den Bosch, R., and Hagen, K. S. (1959). The integration of chemical and biological control of the Spotted Alfalfa Aphid the integrated control concept. *Hilgardia, 29*(2), 81-101.

Streit, J., Meinen, C., Nelson, W. C. D., Siebrecht-Schöll, D. J., and Rauber, R. (2019). Above- and belowground biomass in a mixed cropping system with eight novel winter faba bean genotypes and winter wheat using FTIR spectroscopy for root species discrimination. *Plant and Soil, 436*(1), 141–158.

Thorup-Kristensen, K., Magid, J., and Jensen, L. S. (2003). Catch crops and green manures as biological tools in nitrogen management in temperate zones. *Advances in Agronomy, 79*(79), 227–302.

Tufts, W. P., Allen, F. W., Brooks, R. M., Condit, I. J., Cruess, W. V., Davey, A. E., Davis, L. D., Erdman, H. E., Hansen, C. J., Hendrickson, A. H., Hodgson, R. W., Philp, G. L., Shear, S. W., and Winkler, A. J. (1946). The rich pattern of California crops. In Hutchison, C. B. (Ed.) *California Agriculture.* Berkeley and Los Angeles: University of California Press.

Tworkoski, T. J. and Glenn, D. M. (2012). Weed suppression by grasses for orchard floor management. *Weed Technology, 26*(3), 559-565.

Ugrenović, V., Filipović, V., Jevremović, S., Marjanović-Jeromela, A., Popović, V., Buntić, A., and Delić, D. (2019). Effect of Brassicaceae as cover crops. *Selekcija i Semenarstvo, 25*(2), 1-8.

USDA NASS. (2019). *2019 California walnut objective measurement report*. Sacramento CA: USDA, National Agricultural Statistics Service. Retrieved on May 12, 2021 https://www.nass.usda.gov/

Van Sambeek, J. (2017). Cover crops to improve soil health and pollinator habitat in nut orchards. *Missouri Nut Growers Association (MNGA) Newsletter, 17*(1), 9-11; *17*(2), 6-12.

Yang, J., Liu, R. H., and Halim, L. (2009). Antioxidant and antiproliferative activities of common edible nut seeds. *LWT–Food Science and Technology, 42*(1), 1–8.