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Effects of Summer Cover Cropping on Weed Population Density and Biomass in a Subsequent Broccoli Crop

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Abstract. A three-year field study found that summer cover cropping suppresses weed population densities and their biomass in a subsequent fall vegetable crop. Cover crop weed suppression was stronger on broadleaf than grass weeds. Weed suppression increased with increasing years of cover cropping rotations, indicating that repeated cover cropping is more effective than a single season rotation. Summer cover cropping rotations coupled with supplemental hand weeding further suppressed weeds, suggesting the importance of cover crops as an integrated weed management strategy. The lower supplemental weeding needs associated with cover cropping, compared to the summer fallow indicates the economic benefit of summer cover cropping systems. There were fewer weeds in the subsequent broccoli when preceded with summer cowpea than marigold as a cover crop. Therefore, proper selection of cover crop species, adaptability to local location and suitability with the intended main crop is essential for effectiveness of cover crops as a weed management strategy.

Keywords: Weeds, cover crops, broccoli, weed population density, weed biomass

1. Introduction

Conventional weed management practices that solely depend on intensive use of herbicides cause ecological and health hazards [1], hence triggered societal demand for alternative weed management strategies [2]. Non-chemical weed management strategies are a priority for organic agriculture [3], [4] as specified by the National Organic Regulations and Guidelines. However, the lack of effective non-chemical weed management has limited the intensity of certified organic croplands in the US [5].

Research emphasis has been given to alternative weed management strategies that are ecologically and economically desirable. One of such alternative strategies was the use of cover crops [6], [7], [8]. Many of those researches were based on inter-planting of the cover crops with the main crop. However, most growers are hesitant to use cover crops as inter-planting, because of their competition for resources and yield reduction on the main crop [9]. We believe that cover cropping may be more beneficial and acceptable if used as off-season cropping rotation. There are limited off-season cover cropping research, but the existing ones pointed out the added economic benefits of off-season cover crops [10], [11].

The objective of this research project was to assess the effectiveness of summer cover cropping for weed management in a subsequent fall season broccoli crop. More specifically, we evaluated the responses of major weed population densities and their biomass to cropping strategies; through a) planting cover crops as a summer rotation after which the vegetable crop is planted during the fall season and b) planting the primary vegetable crop on a summer fallow (bare land) as a control treatment. We also assessed the intensity of supplemental hand weeding needs for each of the cropping treatments.

2. Materials and Methods

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2.1. Crop Management

This research was conducted for three consecutive years (2008 to 2010) at the University of California's South Coast Research and Extension Station in Irvine, CA. Three cropping treatments were employed: 1) French marigold (*Tagetes patula* cv. Single Gold) seeded at 2 kg/ha, 2) cowpea (*Vigna unguiculata* cv. UCR CC 36), seeded at 56 kg/ha, and 3) a summer dry fallow as the untreated control. Each treatment plot was 12 m long x 10.7 m wide (128 m^2). The cover crops were direct-seeded in the last week of June in the centre of 14 planting beds for each treatment plot, watered through drip tubing and grown for three months. The fallow control plots did not receive water during the summer. Each cover crop treatment plot was planted with the same cover crop in each of the three years of study. Plots were separated from each other with a 3 m wide buffer of bare ground. The three treatments were replicated four times in a completely randomized design. At the end of the summer cropping period (first-week of September), the cover crops were mowed at the soil line, chopped, and the residues left on the ground. Concurrently, alternate beds (7 of the 14 beds) of each of the cover crop plots were incorporated into the soil at about 0.4 m intervals using rotary tiller in preparation for broccoli transplanting. There was no roto-tilling for the fallow plots

At the beginning of the subsequent fall cropping season (10 days after cover crop incorporation), broccoli seedlings (*Brassica oleracea*, cv Marathon) were transplanted in double rows into the tilled strips of the summer cover crop and fallow plots at an inter and intra-row spacing of 13 and 35 cm, respectively (http://ucanr.org /freepubs/docs /711.pdf). Broccoli transplants were drip irrigated and fertilized with emulsified fish meal (6-2-0 organic fertilizer) at 5 gallons/acre. All plot treatments were maintained in the same location for all three years of study in order to assess a cumulative build-up effect of cover crops over time.

2.2. Weed Population Density and Biomass Sampling

Weed population density was collected at 4 (early), 8 (mid), and 12 (harvest time) weeks after broccoli transplanting. Weed populations were sampled using a 50 cm x 50 cm quadrat randomly thrown twice within each treatment plot, then counting each weed species that had emerged within the quadrant. Population density of each weed within a treatment plot was recorded as the average of the two quadrat counts. Weed dry biomass was determined by clipping the aerial portion of each weed species observed within each quadrat, drying the samples for 7 days at 700C, and then weighing. The total weed dry biomass of each weed species was recorded and averaged for the two quadrat samples per plot. Weed species population density and dry biomass data were analysed using ANOVA and the means separated using the student T-test.

2.3. Assessment of Supplemental Hand Weeding Hours

Following each of the early and mid-season weed samplings, each treatment plot was hand weeded to remove all weeds and recorded as initial (first) and second hand weeding, respectively. The time (man-hours) it has taken for each hand weeding of each plot was recorded for each plot separately.

3. Results and Discussion

3.1. Effects of Cover Crops on Weed Population Density

The most dominant weed species during all trial years was common purslane (*Portulaca oleracea*), accounting for 70-85% of all weed populations. Other broadleaf weeds included common lambsquarters (*Chenopodium album*), black nightshade (*Solanum nigrum*), Amaranth (*Amaranthus* species), bull mallow (*Malva nicaeensis*), annual sowthistle (*Sonchus oleraceus*), field bindweed (*Convolvulus arvensis*), shepherd's-purse (*Capsella bursa-pastoris*) and redstem filaree (*Erodium cicutarium*). Burning nettle (*Urtica urticaurens*) and creeping woodsorrel (*Oxalis corniculata*) were observed in some plots, but rarely. The grass weed species barnyardgrass (*Echinochloa crus-galli*) and Mediterranean lovegrass (*Eragrostis barrelieri*) occurred very sporadically.

Population density of common purslane during the early weed sampling of 2008 was 370 plants per m2 for the fallow plot and only 34 and 82 for the marigold and cowpea plots, respectively (Table 1). The population density of all weeds combined (mostly accounting for purslane population) at this sampling period was also reduced by 5 and 4 times under marigold and cowpea, respectively compared to the fallow plot. The results clearly demonstrate the importance of preceding fall vegetable crops with summer cover crops for an effective suppression of weeds. Grass weeds were generally few and did not vary among cropping treatments, hence the cover crops were more suppressive to the broadleaf than to the grass weeds. During mid and harvest time sampling, which followed supplemental hand weeding, weed population densities declined very significantly for all cropping treatments, relative to the early sampling. The combined total weed population densities at those sampling periods were still lower within the cover crops than in the fallow plot (Table 1).

Table 1: Weed population density per m2 for the early, mid, and harvest time sampling*

Weed species	Weed sampling time and cropping treatments								
	Early			Mid			Harvest		
	mg	cp	fw	mg	cp	fw	mg	cp	fw
2008 (1st year)									
Common purslane	34a	82a	370b	2a	10a	36a	0a	8a	36a
All broadleaves**	65a	105a	409b	29a	26a	57a	23a	21a	64b
All grasses***	22a	5a	24a	5a	6a	26a	2a	2a	21a
All Weeds	87a	110a	433b	33a	32a	82b	25a	23a	85b
2009 (2nd year)									
Common purslane	96a	85a	331b	7a	10ab	40b	6a	9a	63b
All broadleaves	128a	115a	415b	11a	14a	58b	33a	17a	87b
All grasses	9a	15a	23a	3a	2a	5a	6a	2a	7a
All Weeds	137a	130a	437b	14a	16a	62b	39a	19a	94b
2010 (3rd year)									
Common purslane	32a	16a	197b	5a	3a	11b	0.3	0.5	0.0
All broadleaves	64a	24a	281b	26ab	14a	44b	13ab	3a	15b
All grasses	1a	0a	7a	2a	0a	2a	0.3a	0a	1a
All Weeds	65a	24a	288b	28ab	14a	46b	13ab	3a	16b

Table 2. Weed dry biomass (g/m2) for early, mid, and harvest time weed sampling*

Weed species	Weeding sampling time and cropping treatments								
	Early			Mid			Harvest		
	mg	cp	fw	mg	cp	fw	mg	cp	fw
2008 (1st year)									
Common purslane	0.1a	0.3a	11b	0.0a	0.1a	0.0a	0.0a	0.1a	4.0a
All broadleaves**	0.3a	0.3a	11b	0.1a	0.1a	0.1a	1.0a	1.1a	7.6a
All grasses***	0.1a	0.0a	0.2a	0.0a	0.0a	0.0a	0.0a	0.0a	0.6a
All Weeds	0.4a	0.3a	11b	0.1a	0.1a	0.1a	1.0a	1.1a	8.1a
2009 (2nd year)									
Common purslane	6a	10a	28b	1.0a	1.1a	4.4b	0.6a	2ab	12b
All broadleaves	7a	11a	32b	1.1a	1.5a	10b	2a	4a	20b
All grasses	0.6a	0.8a	2.7a	0.6a	0.1a	0.6a	1.5a	0.7a	1.8a
All Weeds	8a	12a	35b	1.7a	1.6a	11b	3a	5a	22b
2010 (3rd year)									
Common purslane	6a	10.1a	19a	0.83a	0.51a	1.46a	.01a	0.03a	0.0a
All broadleaves	15a	13a	38b	5a	5a	24b	3a	1a	10b
All grasses	3a	0.0a	2.3a	0.13a	0.0a	0.81a	.03a	0.0a	0.10a
All Weeds	18a	13a	40b	5a	5a	25b	3a	1a	10b

* Horizontal mean values for each weed species within each sampling time followed by different letters are significantly different from each other (mg = marigold, cp = cowpea and fw = fallow.

** Broadleaf weeds (Common lambsquarter, Black nightshade, Amaranth, Redstem filare, Sowthistle, Field bindweed, Shepherd's purse). Amaranth species were *A. albus*, *A. sinosus* and *A. retroflexus*.

*** Grass weeds = Barnyardgrass, Mediteranean lovegrass

Similar trends of weed population densities, as in 2008 were observed in 2009. Common purslane continued to be the most dominant, but 3 and 4 times fewer in marigold and cowpea plots, respectively compared to the summer fallow plot (Table 1). There were less common purslane and all weed species combined in all cropping treatments during the mid and harvest time samplings, relative to the early sampling period (Table 1), and relatively less populated under the cover crop, compared to the fallow plot. Broadleaf weeds are still the most affected by cover cropping treatments than grass weeds (Table 1). Weed population densities at any sampling stage were generally the least in 2010 compared to the previous years. Considering the early sampling for this year, common purslane was 6 and 12 times less dense in marigold and cowpea, respectively compared to the fallow (Table 1), indicating consistent activity of cover crops over many years of cropping rotations. While weed densities at mid and harvest time sampling are less than the early sampling for all treatments of this year as well, they were much less populated in the cowpea plots, relative to the same sampling period of the fallow plot.

3.2. Effects of Summer Cropping System on Weed Dry Biomass

Consistent with its population densities, common purslane had the highest biomass accumulation than any other weed at all weed sampling periods of all years (Table 2). At early sampling in 2008, common purslane had about 100 and 36 times higher dry mass in the fallow plot, relative the marigold and cowpea plots, respectively. Dry mass of all weeds combined was also about 28 or 36% higher within the fallow compared to marigold or cowpea plots, respectively. Weed dry mass at mid and harvest time samplings was not significantly different among cropping treatments (Table 2), probably attributing to the depletion of weed seed banks following supplemental hand weeding. Dry mass of common purslane and that of all weeds combined were still significantly higher for the fallow plots in 2009 than in the cover crop plots (Table 2). Also, as in the previous year, weed dry mas following subsequent supplemental hand weeding (at the mid and harvest time) were lower than weed dry mass at the early sampling. Weed dry masses at any given sampling in 2010 was the least compared to the previous year’s (2008 and 2009) respective sampling periods, confirming that extended years of cover cropping and supplemental weeding could provide the most efficient control on weeds.

3.3. Summer Cover Cropping and Supplemental Weeding Needs

Supplemental hand weeding hours for initial weeding (accomplished immediately after early weed sampling) in 2008 was not significantly different among the cropping treatments (Fig. 1). At the second supplemental hand weeding, less hours was required for the cover crop plots than the fallow plots, indicating the benefits of combining cover cropping with supplemental weeding. During the subsequent cover cropping rotations (2009 and 2010), significantly less hand weeding hours were required for the cover crop plots, particularly for the cowpea, starting at the initial supplemental hand weeding and then after (Fig. 1), compared to the respective weeding periods in the fallow plot. Those results clearly demonstrate that increasing years of cover cropping rotation may provide increasing intensity of weed suppression. The hours required for supplemental hand weeding hours were somehow related to the degree of weed population densities within the giver cropping treatment plots.

In general, common purslane (*Portulaca oleracea*) was the most predominant weed during all experimental years and weed sampling periods, may attributing to its prolific seed production and rapid land colonization capacity [12]. Never the less, its population density and biomass production in a fall crop can be suppressed with planting purslane infested fields with cover crops during the summer season. The capacity of summer cover crops to suppress weeds as shown during the early sampling (before supplemental hand weeding) indicates that cover crops could help the subsequent crop to overcome weed competition during the crop’s early growth stages. Crops that overcome early stage resource completion may grow vigorously and produce early dense canopies [13] that in itself can suppression subsequent weed growth [14]. Since the broadleaves were more suppressed than grass weeds, summer cover cropping may be more beneficial in agricultural fields that are dominated by broadleaf weeds. This deduction agrees with the findings of [15] who has observed stronger broadleaf suppression than grasses by sun hemp cover crop mulches.

Our results also showed stronger weed suppression with increasing years of cover cropping rotations, which may be a manifestation of the build-up effect of cover cropping systems. On the other hand, the relatively stronger weed suppression with cowpea cover cropping than with marigold may be attributed to the leguminous and N fixing capabilities of cowpea and its huge biomass production that ultimately benefits the subsequent crop [16], [17]. Although, our results showed a strong weed suppression with cover cropping, it must be noted that it is not a complete weed control, hence the need for supplemental weeding. That was why [18] emphasize that cover crops should not be regarded as sole weed management strategy, but as contributors to an integrated weed management practices. Our results clearly demonstrated that a complete weed control was rather achieved with the integration of summer cover cropping with supplemental hand weeding. As part of an integrated weed management option, we have shown that summer cover cropping reduced the amount of supplemental hand weeding (Fig. 1). The results showed that at any given weeding period, required supplemental weeding hours in the fallow plot was almost double that of the time required for total weed removal in either of the cover crop plots. Reducing the amount of supplemental weeding hours, contributes to the reduction of crop production costs and maximizes economic returns.

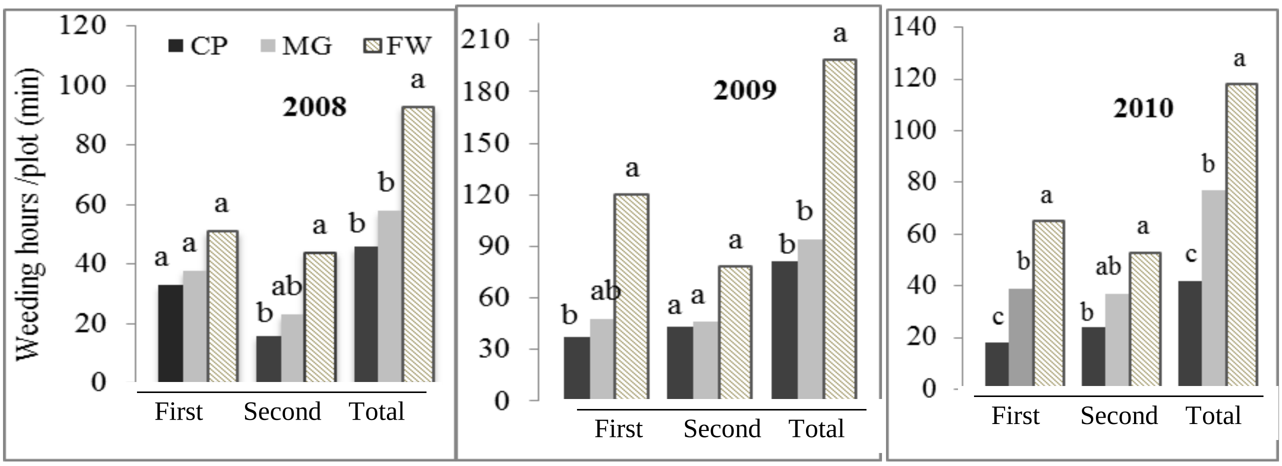

Fig. 1: Duration (minutes) for first, second and total hand weeding for three cropping treatments (CP = cowpea, MG = Marigold and FW = fallow plots) for 2008 (left), 2009 (middle) and 2010 (right)

The mechanism (s) by which the cover crops might have suppressed weeds is not clear. Various reasoning exists in literature. For example [12], suggested that cover crop residues suppress weeds by modifying their soil microclimate or by physically impeding weed seed germination, while [17], [7] consider inhibition of light penetration through the cover crop residues to be the main reason. On the other hand, [19], [20] pointed out that cover crops enhance soil microbial populations that indirectly depletes soil weed seed bank. Many others have also given an emphasis to allelopathic potential of cover crops against weeds [21], [22], [6], even a selective phytotoxicity of cover crop allelochemicals to broadleaf weeds [23], [24]. While we have observed stronger suppression of broadleaf weeds with cowpea and marigold cover cropping, we are not sure if that was as a result of allelopathic influences or any other factor, thus requires future study and analysis. Proper and detailed understanding of cover crop allelopathy may aid scientists to develop effective biological weed control strategies [21] and reduce future reliance on synthetic herbicides [25]. Cover crops were not only useful in suppressing weeds, but are also ecologically desirable practice. Although such practice may be more appealing to organic crop production, where chemical weed control is not an option, they may also be useful as an integrated weed management in conventional crop production systems. Furthermore, off-season cover cropping may improve local biodiversity and enhance beneficial arthropods and saprophytic nematodes that may help control other pests or improve soil conditions [13].

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