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Effect of living mulches on yield components of sunflower (*Helianthus annuus* L.) and weed seed productivity in line with sustainable agriculture

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Key words: Living mulches, hairy vetch, rapeseed, triticale, weed management.

Abstract

In order to evaluate the effects of some cover crops as living mulches on yield components of sunflower (*Helianthus annuus* L.) and weed seed productivity in sunflower field, an experiment was done in 2012 at the Research Field of Tabriz University, Iran. The experimental design was a randomized complete block with nine treatments in three replications. Treatments included triticale, hairy vetch, rapeseed, triticale + hairy vetch, triticale + rapeseed, hairy vetch + rapeseed, application of trifluralin herbicide, and controls (weed infested and weed free without planting cover crop). Result indicated than in all cover crops treatments weeds seed production was reduced. Maximum reduction in seed production for total weed species was observed in hairy vetch + rapeseed (69.17%), and also 65.37% reduction in weed seed productivity was observed in triticale + rapeseed compared to weed infested treatment. Although weed seed production was reduced due to presence of these living mulches, but yield components of sunflower were significantly affected by treatments, too. Triticale had lowest effect on yield components of sunflower. On the other hand, not significantly differences were found between trifluralin usage and triticale. Using of living mulch as a strategy to reduce the damage of weeds and application of herbicide can be helpful in integrated weed management and sustainable agriculture.

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Introduction

Weeds are a serious constraint to increased production in crops due to reduced yield and economic returns around the world, and we are trending toward controlling these unwanted plants by herbicides, which comes with an increased environmental impact. Discovery of synthetic herbicides in the early 1930s, cause a shift in control methods toward high input and target-oriented ones (Singh et al., 2003).

Even with herbicides, weeds remain prominent in croplands and producers still lose considerable crop yield due to weeds (Bridges, 1994). Furthermore, herbicide resistance is forcing producers to use more expensive management tactics, thereby increasing production costs. Moreover, ground and surface water pollution by these synthetic chemicals are causes for concern (Hallberg, 1989). Improving water quality and decreasing herbicide carry over is one of the more important environmental issues for farmers and agriculture researchers (Stoller et al., 1993). Herbicide-resistant weed ecotypes are being discovered more frequently, due to increased herbicide applications and subsequent selection, is also posing a serious threat to agricultural production (Holt and LeBaron, 1990).

There is an urgent need to develop alternative weed control methods for use in agroecosystems. Increased interest in sustainable agricultural systems has led to significant developments in cropping practices over the past decade (Thiessen-Martenes et al., 2001). In sustainable agriculture, an alternative method to chemical and mechanical weed control in crops is the use of living mulches. Living mulches are cover crops grown simultaneously with the main crop that can suppress weed growth significantly without reducing main crop yield through an ability to grow fast or because they are planted at a high density (De Haan et al., 1994).

Living mulches have the potential to form an important component in agroecosystems and can be a useful tool for weed suppression in sustainable agricultural systems (Teasdale, 1996; Bond and Grundy, 2001; Kruidhof et al., 2008) including many useful advantages such as: improvement of soil structure (Harris et al., 1966), regulation of soil water content (Hoyt and Hargrove, 1986), enhancement of soil organic matter, carbon dynamics and microbiological function (Steenwerth and Belina, 2008), reducing soil erosion (Malik et al., 2000) and reduce economic risk (Hanson et al., 1993).

Investigations showed that weed species seed germination and seedling emergence will suppress due to presence of living mulch (Creamer and Baldwin 2000; Blackshaw et al. 2001; Grimmer and Masiunas 2004; Peachey et al. 2004; Brennan and Smith 2005). Living mulch by occupying the open species between the main crops that would normally be covered by different weed species due to competition for the light, water, and nutritional resources cause this suppression. Establishment of living mulch before main crop and weeds emergence by covering the soil surface and diverse the microenvironment cause reducing in weed species density and diversity. According to Teasdale (1996), change in biological and physical environment at the soil surface due to presence of living mulches support opportunities for controlling and minimizing of weed populations. On the other hand, attendance of cover crops as living mulches leads to greater weed species seed mortality by favoring predators (Cromar et al. 1999).

Research showed that the highest maize grain yields were obtained from 22 plants m^{-2} of cowpea living mulch density probably due to reduced effect of weed competition (Akobundu, 1993). Also Cover crops lowered striga weed population as a result of which the subsequent cereal crop increased in yield compared to farmer practice (Onyango et al., 2000). Similarly, when sunhemp (*Crotolaria ochroleuca*) was used as a green manure cover crop for one year, the maize crop planted subsequently had higher yields (2.4 t/ha) and control (1.4 t /ha) (Obaga et al., 2000). In an experiment in Rachuonyo, Lablab (*Lablab purpureus*) as cover crop together with conservation tillage gave maize grain yields of 2.6 t/ha against 1.8 t/ha of control (Nzabi, 2000). The objective of this study was survey effect of triticale (× *Triticosecale*), hairy vetch (*Vicia villosa* Roth.) and rapeseed (*Brassica napus* L.) as a living mulch on yield components of sunflower (*Helianthus annuus* L.) and weed seed production.

Materials and methods

Field study and cover crops treatment

This study was conducted in 2012 at the research field of Tabriz University, Iran (38°01′ North latitude, 46°25′ East longitude and an altitude of 1676 meters). The soil type was loam (42.4% sand, 38% silt, 19.6% clay, 0.17% organic matter, PH 7.4, and Ec 0.93 ds/m). The experimental design was a randomized complete block with nine treatments and three replications. Treatments included planting triticale, hairy vetch, rapeseed, triticale + hairy vetch, triticale + rapeseed, hairy vetch + rapeseed two weeks before sunflower (*Helianthus annuus* L) planting, application of trifluralin herbicide (2,6-Dinitro-*N,N*-dipropyl-4-(trifluoromethyl) aniline) two weeks before sunflower planting, and controls (weed infested and weed free without planting cover crops before sunflower planting). Triticale, hairy vetch, rapeseed were down furrow drilled at 180, 45, and 9 $kgha^{-1}$, respectively. These plants were grown during sunflower growing seasons. Oil hybrid sunflower cv. Urofoure was direct top of the furrow drilled (seven rows per plot; 50 cm row spacing; 86,000 seeds ha^{-1}) two week after cover crop planting.

Study of Weed seed production and yield components of sunflower

To evaluate the effects of living mulches on seed production in weed species and yield components of sunflower at the end growing season was sampled. In each plot, weed species, their seed production were measured and yield components such as cap diameter, cap weight, seed per cap, biological yield, 1000 seed weight, seed yield and finally oil of the seed were calculated. Percentage inhibition or stimulation of germination was calculated according to the following equation:

$$\text{Inhibition (-) or stimulation (+)} = \frac{GST - Gsc}{GSC} \times 100$$

Where GST is germination seeds in treatments and GSC is germination seeds in control (Hassannejad & Porheidar-Ghafararbi, 2013). Data were analyzed using SAS (Ver. 9.1) and mean comparison was conducted according to the Duncan's t-test.

Results and Discussion

Weed seed productivity

Analysis of variances indicated that Weed seed productivity was significantly affected by treatments (Table 1).

Table 1. Analysis of variances for weed species seed production (Che.alb = *Chenopodium album* L., Con.arv = *Convolvulus arvensis* L., Set.vir.= *Setaria viridis L.*, Ama.spp.= *Amaranthus sp*, Lot.cor.= *Lotus corniculatus* L.)

S.O.V	df	Che.alb.	Con.arv.	Set.vir.	Ama.spp.	All weeds
Replication	2	3541663.1 ns	17810 ns	124512.4 ns	3112814.6 ns	9131623.1 *
Treatments	8	4838612.5 **	117403 **	6546321.2 **	5473652.4 **	43760401 **
Error	16	512561.2	14386.6	55313.6	673537.2	1679121.7
CV (%)	-	13.71	31.32	23.83	12.21	14.51

*=Significant at 5% level, **= Significant at 1% level, ns=Non-significance

Main weed species observed in our experimental field were common lambsquarters (*Chenopodium album* L.), bindweed (*Convolvulus arvensis* L.), green bristlegrass (*Setaria viridis* L.), pigweed (*Amaranthus sp),* and birdsfoot trefoil *(Lotus corniculatus* L.). Mean comparisons showed that common lambsquarters, bindweed, and pigweed had highest density in weed infested treatment, but lowest density of common lambsquarters, green bristlegrass and pigweed were observed in hairy vetch + rapeseed cover crop. The highest density of green bristlegrass was observed in hairy vetch and weed infested treatments. In weed free treatment, bindweed had lowest density (Figure 1).

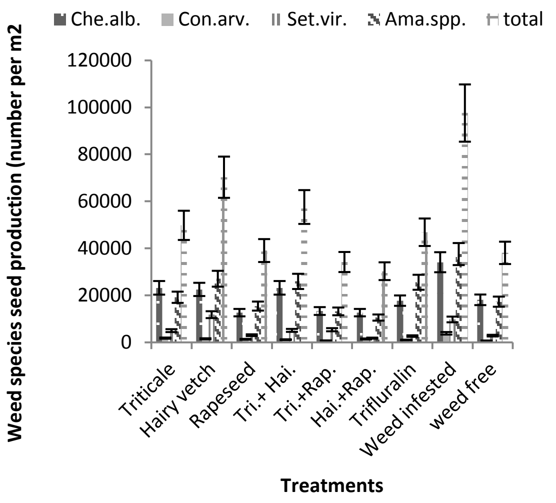

Fig. 1. Effects of living mulches on weed seed productivity. Tri.= triticale, Hai.= hairy vetch, Rap.= rapeseed; Che. alb.=*Chenopodium album* L., Con.arv = *Convolvulus arvensis* L., Set.vir.= *Setaria viridis* L., Ama.spp.= *Amaranthus* sp.

In all cover crops treatments weeds seed productivity was reduced. So that, maximum reduction in total weed species seed productivity was observed in hairy vetch + rapeseed (69.17%) and also 65.37% reduction in weed seed productivity was observed in triticale + rapeseed compared to weed infested. Minimum reduction in total weed species seed productivity was observed in hairy vetch cover crop (28.51%). Common lambsquarters, green bristlegrass and pigweed seeds was reduced 63.81% , 82.67% and 72.67% in hairy vetch + rapeseed, respectively compared to weed infested treatment (Table 2). Weed-suppressive ability is the ability to suppress weed growth and reduce weed seed production and, hence, benefit weed management in the subsequent growing season (Jannink et al., 2000; Zhao et al., 2006). Gaskin (2006) reported that biological control methods that focus on reducing or eliminating seed production would do little to stop expansion of a patch. Also investigations showed that the presence of fall rye can decrease the seed production of *Portulaca oleraceae* L. (Mohler and Callaway, 1995).

Table 2. Percent inhibition of treatments on weed species seed production (Che.alb = *Chenopodium album* L., Con.arv = *Convolvulus arvensis* L., Set.vir.= *Setaria viridis L.*, Ama.spp.= *Amaranthus sp*, Lot.cor.= *Lotus corniculatus* L.)

Treatments	Che.alb.	Con.arv.	Set.vir.	Ama.spp.	All weeds
Triticale	-32.14 b	-54.67 c	-49.53 c	-49.45 b	-49.31 b
Hairy vetch	-34.85 b	-61.13 b	+21.38 d	-28.78 c	-28.51 c
Rapeseed	-63.42 a	-67.65 ab	-69.61 b	-58.98 b	-60.76 ab
Triticale + Hairy vetch	-37.59 b	-71.21 ab	-48.21 c	-31.54 c	-41.35 bc
Triticale + Rapeseed	-61.31 a	-82.23 a	-45.31 c	-65.34 ab	-65.37 a
Hairy vetch + Rapeseed	-63.81 a	-63.63 b	-82.31 a	-72.67 a	-69.17 a
Application of trifluralin	-48.47 ab	-75.71 ab	-73.32 b	-32.39 c	-52.38 b
Weed free	-47.42 ab	-83.67 a	-71.38 b	-54.12 b	-61.54 ab

+ have additive effects and - is a inhibition effect.

Yield components of sunflower

Although analysis of variances indicated that yield components of sunflower such as cap diameter, cap weight, seed per cap, biological yield and seed yield was significantly affected by treatments, 1000 seed weight and oil did not effected by treatments (Table 3).

Table 3. Analysis of variances for yield components of sunflower (*H. annuus*)

S.O.V	df	Cap diameter	Cap weight	Seed per cap	Biological yield	1000 seed weight	Seed yield	oil
Replication	2	1.45 ns	24.82 ns	28912.25	65.58 ns	36.71 ns	810986.93 ns	5.58 ns
Treatments	8	21.13 **	521.16 **	206732.28 **	4182.3 **	114.82 ns	11825726.36 **	10.72 ns
Error	16	2.31	101.31	12731.38	371.37	44.64	123717.5	5.73
CV (%)	-	8.03	25.54	10.56	22.99	15.69	30.58	4.55

*=Significant at 5% level, **= Significant at 1% level, ns=Non-significance

All living mulch reduced sunflower cap diameter (Figure 2), cap weight (Figure 3), number of seed per cap (Figure 4), biological yield (Figure 5) and seed yield (Figure 6). Rapeseed caused maximum reduction in yield components of sunflower, however triticale had lowest effect on this subject. There was not significantly differences between trifluralin and triticale.

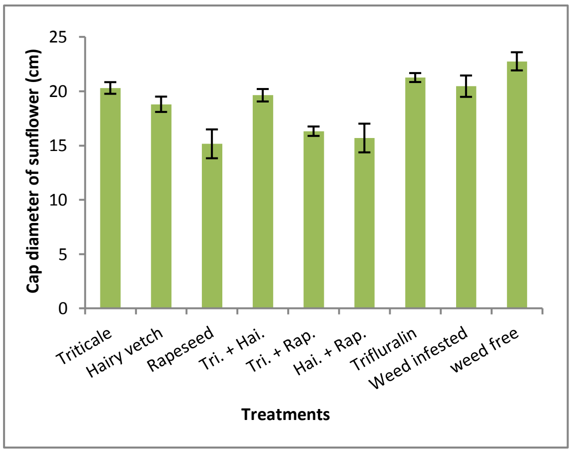

Fig. 2. Effects of living mulches on cap diameter of sunflower. Tri.= triticale, Hai.= hairy vetch, Rap.= rapeseed.

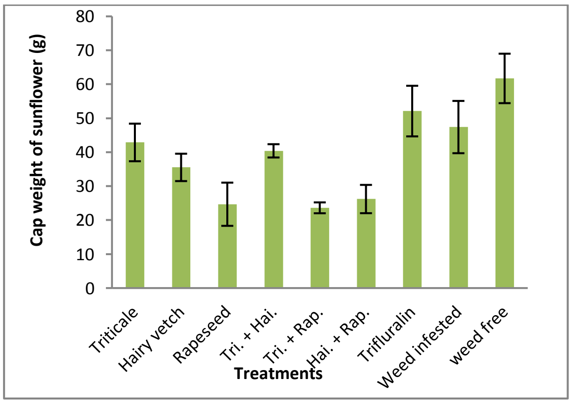

Fig. 3. Effects of living mulches on cap weight of sunflower. Tri.= triticale, Hai.= hairy vetch, Rap.= rapeseed.

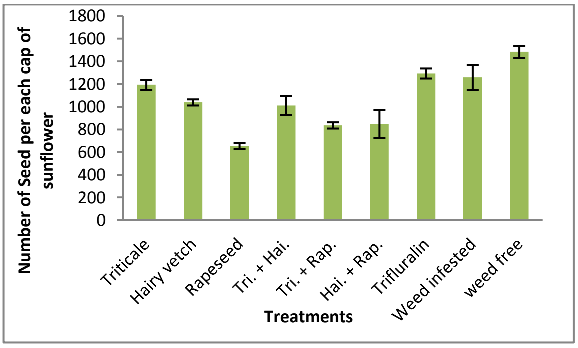

Fig. 4. Effects of living mulches on number of seeds per each cap of sunflower. Tri.= triticale, Hai.= hairy vetch, Rap.= rapeseed.

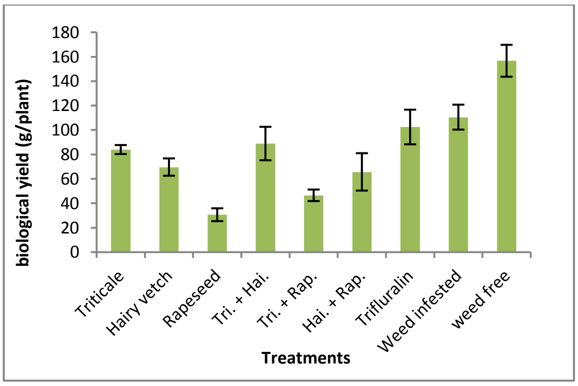

Fig. 5. Effects of living mulches on biological yield of sunflower. Tri.= triticale, Hai.= hairy vetch, Rap.= rapeseed.

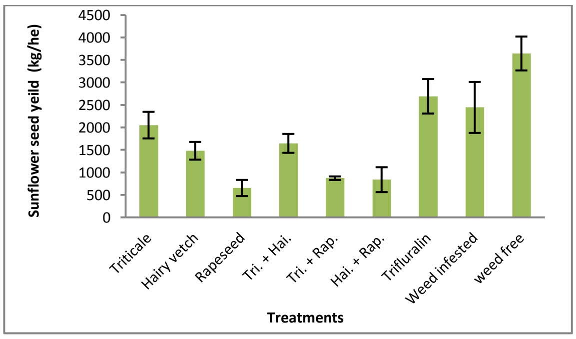

Fig. 6. Effects of living mulches on sunflower seed yield. Tri.= triticale, Hai.= hairy vetch, Rap.= rapeseed.

Investigations showed that high yields and good quality of cabbage, broccoli, pepper and sweet corn was obtained when these plants were growing within white clover as a living mulch (Finch, 1993; Guldan et al., 1996; Infante and Morse, 1996; Starck et al., 1996). Although living mulches can efficiently suppress weeds, but it is may be they can compete for nutrients and water with the main crop (Echtenkamp and Moomaw, 1989) and cause reduction in yields. For example, Pederson et al. (2009) found that crop yields planted in living mulch systems under different suppression regimes were lower than crop yields in a clean-till system (without liing mulch). Management of living mulches becomes critical to reduce competition with the main crop for resources while allowing the mulch to grow sufficiently to reap potential benefits. Different ways have been suggested to overcome this problem in such cropping systems. One of them is the selection of suitable living mulch species and the others have been employed to suppress the living mulch, such as tillage, mowing, and herbicides (Grubinger and Minotti, 1990; Fischer and Burrill, 1993; Costello, 1994; Martin et al., 1999; Zemenchik et al., 2000).

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