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Research Article

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Investigation the use of living and non-living mulches in weed control of coriander (*Coriandrum sativum* L.)

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ABSTRACT- Weeds are the most important limiting factors in agricultural systems and the use of mulch is considered as a suitable solution in the ecological management of weeds. In order to evaluate the coriander yield and its weed control, a factorial experiment was conducted at the research farm of the Faculty of Agriculture, University of Zanjan in 2020. The first factor was the types of mulches including ratios of 100 % (40.0 kg ha^{-1}), 66 % (26.4 kg ha^{-1}), and 33 % (13.2 kg ha^{-1}) of clover (*Trifolium alexandrinum* L.) and 100 % (20.0 kg ha^{-1}), 66 % (13.2 kg ha^{-1}), and 33 % (6.6 kg ha^{-1}) of alfalfa (*Medicago scutellate* L.) as living mulches, wheat straw (*Triticum aestivum* L.) (one kg m^{-2}) as a non-living mulch, and a non-mulched treatment and the second factor was weed control including complete weed control, once-weed control and non-weed control. The results showed that the effects of the treatments of mulch type and weed control were statistically significant on the components of yield and yield of coriander. The highest grain yield (1601.4 kg ha^{-1}), biomass yield (3901.0 kg ha^{-1}) and essential oil yield (3.35 kg ha^{-1}) were recorded in wheat straw mulch under complete weed control conditions. Clover at densities of 100 % and 66 % caused suffocation and complete destruction of coriander plants. Therefore, the grain yield and biomass production of coriander in these treatments were equal to zero. Alfalfa at low densities had no significant effect on weed control. Complete control of weeds caused a significant increase in all evaluated traits in coriander. The results of the present study showed that wheat straw mulch is a suitable solution for controlling coriander weeds, which not only does not interfere with the growth of coriander but also causes effective control of its weeds. Therefore, considering the importance of integrated control of weeds in sustainable agricultural systems, the use of wheat straw mulch can be introduced as one of the strategies to reduce the use of chemical pesticides and reduce environmental pollution.

INTRODUCTION

Coriander (*Coriandrum sativum* L.) is an annual herb in the family of Apiaceae. All parts of this plant are edible, but the fresh leaves and the dried seeds (which are both a herb and a spice) are the parts most traditionally used in cooking. Coriander has various and important uses as a medicinal plant. This plant is appetizing, anti-flatulence, digestive food, soothes nerves and rheumatic pains and lowers blood sugar. Its essential oil is used as a spice in the beverage, food and cosmetics industries. Coriander is a poor competitor, especially against perennial weeds. Because coriander is a short plant, it needs more time to germinate and has slow vegetative growth, so it is very susceptible to early competition with weeds (Savaliya et al., 2017). Generally, Weeds can cause yield loss and excessive dockage losses in this plant.

Given the pressing needs to diversify weed control programs, limit land degradation, and address environmental issues associated with intensive farming, it has been believed that mulches merit increased attention. Living mulches are annual or perennial cover crops grown during the growing season of the main crop. Numerous studies have demonstrated the capacity of living mulches to diminish the need for intensive tillage, reduce soil erosion and nitrate leaching, and regulate of soil temperature (Andrews et al., 2020; Qi et al., 2011; Siller et al., 2016). Weed suppression is one of the most important functions of living mulches. Mechanisms of weed suppression by living mulches have been reported to be included inhibition of weed seed germination by shading, competition for light and nutrients, and allelopathy (Mediene et al., 2011; Petit et al., 2018). For example, the allelopathic chemicals of winter rye (*Secale cereale*), ryegrasses (*Lolium spp*), and sub-terrain clover (*Trifolium subterraneum*) could be used to control weeds in corn (*Zea mays*) and beans (*Phaseolus vulgaris*) (De Gregorio and Ashley, 1986). In a study it was reported that using of black oat or rye cover crops has the potential to increase cotton productivity and reduce herbicide inputs for cotton (Reeves et al., 2005). Also, it has been shown that the use of crop residues as non-living mulches is an important management tools to pose positive effects on soil and crop growth (Akhtar et al., 2018a, 2018b). Straw mulch retained more rain water and also had positive response on soil water content by controlling evaporation loss (Ali et al., 2018; Ghosh et al., 2006) and hence decreased the soil temperature due to low thermal conductivity (Ali et al., 2018).

Generally, the studies on mulches suggested that high-precision, multipronged management approaches result in weed control and yield outcomes (Bhaskar et al., 2021). Ideally, many aspects of cropping system management contribute to competitive environments in which mulches promote weed suppression without outcompeting main crops. The design of management programs should reflect a long-term perspective. For example, weed suppression should be done in a way that is relevant not only to the yield of the main crop, but also to the production of weed seeds. Management programs that kill weeds while providing milder mulch suppression could limit additions to weed seedbanks (Bhaskar et al., 2021).

The aim of the present study was not to describe the benefits of mulches, many of which have been summarized in the articles cited above. Instead, in this study evaluate mechanical methods of maximizing weed suppression and minimizing mulch-crop competition were evaluated. In other words, the purpose of this study was to characterize management practices that can increase the likelihood of positive outcomes (good weed suppression and the high yield of coriander as a main crop) using living (clover and alfalfa) and non-living (wheat straw) mulch systems.

MATERIALS AND METHODS

Time and location of the experiment

This experiment was carried out at the research farm of the Faculty of Agriculture, University of Zanjan, Zanjan, Iran (36° 41' N, 48° 29' E, altitude 1663 m) in 2020. Soil properties of the experimental field are shown in Table 1. Also, precipitation, average temperatures, average minimum and maximum temperatures, and average relative humidity during the months of the research are shown in Table 2.

Experimental Design

This study was performed as a factorial based on a randomized complete block design with three replications. The first factor was the types of mulches including ratios of 100 % (40.0 kg ha^{-1}), 66 % (26.4 kg ha^{-1}), and 33 % (13.2 kg ha^{-1}) of clover (*Trifolium alexandrinum* L.) and 100 % (20.0 kg ha^{-1}), 66 % (13.2 kg ha^{-1}), and 33 % (6.6 kg ha^{-1}) of alfalfa (*Medicago scutellate* L.) as living mulches, wheat straw (*Triticum aestivum* L.) (one kg m^{-2}) as a non-living mulch, and a non-mulched treatment and the second factor was weed control including complete weed control (weeding by the end of the growing season, manually), once-weed control (weeding by about 35 days after the main plant grows, manually) and non-weed control.

Each plot was five meters long and two meters wide and consisted of eight rows with a distance of 25 cm between the rows. The distance between the plots was 50 cm. Coriander seeds were sown at a depth of 2-3 cm in the soil with a distance of 10 cm on the rows and 25 cm between the rows (density of 40 plants per square meter). To provide non-living mulch, one kg per square meter with a thickness of seven cm wheat straw was added at intervals between rows of coriander. Clover and alfalfa were also planted with, 100, 66, and 33 % ratios among the main plant (coriander) rows. Irrigation was carried out once a week using a drip irrigation system.

Farm Weeds Flora

The weeds flora in the experimental field included 17 species (Table 3). *Amaranthus retroflexus* L., *Amaranthus blitoides* S., *Chenopodium album* L., *Sencio vulgaris* L., *Alopecurus myosuroides* H. and *Malva neglecta* W. had the highest weed density in the experimental field.

Table 1. Soil properties of the experimental field.

Ca (mEq/l)	Mg (mEq/l)	K (mg/kg)	P (mg/kg)	N (%)	Sand (%)	Silt (%)	Clay (%)	Lime (%)	pH	EC (dS/m)	Organic matter (%)
2.1	1.1	286	9.6	0.09	40	27	33	7.2	8.28	2.42	1.18

Table 2. Precipitation, average temperatures and average minimum and maximum temperatures, and average relative humidity during the months of this study in 2020.

Parameters	April	May	June	July	August	September
Precipitation (mm)	52.9	46.6	7.5	15.2	2	0
Average temperature (°C)	7.9	14.2	21.7	23.2	24.3	21.2
Average maximum temperature (°C)	13.7	21.1	31.4	31.6	33.1	30.6
Average minimum temperature (°C)	2.2	7.4	12	14.8	15.5	11.8
Average relative humidity (%)	65	57	32	41	45	39

Table 3. Weeds flora in the experimental field.

Weed species	Growth shape	Photosynthetic pathway
Alopecurus myosuroides H.	narrow-leaved	C3
Amaranthus blitoides S.	broad-leaved	C4
Amaranthus retroflexus L.	broad-leaved	C4
Anchusa italica M.	broad-leaved	C3
Chenopodium album L.	broad-leaved	C3
Cirsium arvense L.	broad-leaved	C3
Convolvulus arvensis L.	broad-leaved	C3
Echinochloa crusgalli L.	narrow-leaved	C4
Erodium cicutarium L.	broad-leaved	C3
Erysimum repandum L.	broad-leaved	C3
Malva neglecta W.	broad-leaved	C3
Salsola kali L.	broad-leaved	C3
Sencio vulgaris L.	broad-leaved	C3
Setaria viridis L.	narrow-leaved	C3
Sinapis arvensis L.	broad-leaved	C3
Solanum nigrum L.	broad-leaved	C3
Xanthium srumarium L.	broad-leaved	C3

Measurements

Traits of Cover Crops

Height, Biomass and Leaf Area Index

Height and biomass of cover crops were measured at two stages of mid-season (2.5 months after planting) and end-of-season (at the physiological maturity stage). For this purpose, 10 plants were randomly selected and their height was measured. Their biomass was also measured after drying in an oven.

To measure the leaf area index of cover crops, at the same time as coriander flowering and weed harvesting, plants in an area of 0.5 m^2 from each plot were randomly harvested. The leaves of the plants were separated and their leaf area was measured using a leaf area meter (Delta-T Devices, Cambridge, UK). The leaf area index was calculated by dividing the leaf area by the ground area.

Traits of Weeds

Density and Biomass

Weeds density and biomass were also measured at the two mid-season and end-of-season stages. Weed density was determined by placing two 0.5×0.5 quadrats randomly inside each plot. Weeds were counted separately and their density was determined. After determining the density, each species was placed in separate bags, then dried in an oven at 75 °C for 48 hours and then weighed.

Traits of Coriander

Number of Sub-branches

At the physiological maturity stage, 10 plants were randomly sampled from each plot and the number of sub-branches was determined.

Yield Components, Grain Yield and Biomass Production

At the physiological maturity stage, 10 plants were randomly sampled from each plot and yield components (number of umbels per plant and umbelets per umbel, the number of seeds per umbel and umbelet, and 1000 seeds weight) were determined. Then, plants in an area of 1.5 square meters were harvested from each plot and after separating the seeds and straws, each of them was dried separately. After air drying coriander seeds in the shade and placing them in an oven at 35 °C for 24 hours, the seeds were weighed and considered as grain yield. The straws of the samples were placed separately in an oven at 75 °C for 48 hours and then weighed. Finally, biomass production was calculated from the total grain and straw yields.

Harvest Index

After calculating grain yield and biomass production, the harvest index was calculated according to equation (1).

$$\text{Harvest index (\%)} = (\text{grain yield}/\text{biological yield}) \times 100 \qquad \text{Equation (1)}$$

Essential Oil Percentage and Yield

To extract the essential oil percentage, 50 g seeds were subjected to hydro distillation using a Clevenger-type apparatus for 3 h (Clevenger, 1928). After measuring essential oil percentage, the essential oil yield was calculated according to equation (2).

$$\text{Essential oil yield (kg ha}^{-1}\text{)} = \text{Essential oil percentage} \times \text{grain yield} \qquad \text{Equation (2)}$$

Statistical Analysis

Analysis of variance was performed using SAS software (version 9.1). The means of the traits were compared by using Duncan's multiple range test at probability ($P \leq 0.05$).

RESULTS AND DISCUSSION

Evaluation of the Traits of Living Mulch

Biomass

The biomass at both mid-season and end-of-season evaluations was significantly affected by mulch type, weed control, and mulch type × weed control effects (Table 4). At both mid-season and end-of-season evaluations, clover at each density had more biomass than alfalfa at the corresponding density (Fig. 1 A and B). The biomass of alfalfa and clover increased with increasing their densities from 33 % to 100 % (Fig. 1 A and B).

At the mid-season evaluation, the highest biomass of living mulch (1105.6 g m^{-2}) was obtained from 100 % clover under complete weed control conditions and the lowest biomass of living mulch (59.05 g m^{-2}) was obtained from 33 % alfalfa under non-weed control conditions (Fig. 1A). However, the biomass of 33 % alfalfa under non-weed control conditions was not significantly different from the biomass of 66 % and 100 % alfalfa under non-weed control conditions and also from the biomass of 33 % and 66 % alfalfa under once-weed control conditions (Fig. 1A).

At the end-of-season evaluation, the highest biomass of living mulch (1052.75 g m^{-2}) was obtained from 100 % clover under complete weed control conditions (Fig. 1B). However, the biomass of 100 % clover under complete weed control conditions was not significantly different from the biomass of 100 % clover under once-weed control conditions and 66 % clover under complete weed control conditions (Fig. 1B). The lowest biomass of living mulch (0 g m^{-2}) was obtained from 33 % alfalfa under non-weed control conditions (Fig. 1B). However, the biomass of 33 % alfalfa under non-weed control conditions was not significantly different from the biomass of 33 % and 66 % alfalfa under complete and once-weed control conditions and also from the biomass of 66 % and 100 % alfalfa under non-weed control conditions (Fig. 1B).

One of the reasons for the superiority of clover over alfalfa, which caused the dominance of clover over alfalfa and proper control of weeds by clover in this study, is suggested to be related to the higher dry weight of clover, which indicated its wider foliage. Evaluation of the leaf area index also showed more leaves and suitable vegetative growth of clover compared to that of alfalfa (Fig. 2). These factors caused the canopy of clover to close faster and thus reduced weed growth and development through shading and restriction of resources.

Leaf Area Index

The leaf area index was significantly affected by mulch type, weed control, and mulch type × weed control effects (Table 4). The highest and lowest leaf area index was obtained from 100 % clover under complete weed control and 33 % alfalfa under non-weed control conditions, respectively (Fig. 2). However, the leaf area index of 33 % alfalfa under non-weed control conditions was not significantly different from the leaf area index of 33 %, 66 %, and 100 % alfalfa under complete and once-weed control conditions and also from the leaf area index of 100 % alfalfa under non-weed control conditions (Fig. 2).

Researchers stated that increasing plant density increases the rate of light absorption and thus increases the rate of crop growth and dry matter production per unit area (Rosalind et al., 2000). As mentioned in the biomass of living mulch section, further propagation of clover foliage than alfalfa resulted in more effective weed control. Clover had more canopy cover than alfalfa and it seems that the presence of more vegetation per unit area is the most important factor that has caused the dominance of clover over the coriander. Lack of weed control caused a significant decrease in leaf area index in all alfalfa and clover densities. By removing weeds, competition between weeds and alfalfa and clover plants was eliminated and suitable conditions were provided for the growth of alfalfa and clover plants.

Height

The height at the mid-season evaluation was significantly affected by mulch type and mulch type × weed control effects (Table 4). Also, the height at the end-of-season evaluation was significantly affected by mulch type, weed control, and mulch type × weed control effects (Table 4). At both mid-season and end-of-season evaluations, the height of alfalfa was significantly lower than that of clover (Fig. 3 A and B). It was supposed that high height, leaf area index and dry weight of clover were the factors that caused clover to dominate over coriander and weeds, and ultimately caused the suffocation of coriander plants.

Table 4. Analysis of variance for different traits including plant height, biomass and leaf area index of living mulches.

SOV	DF	MS				
		Mid-season evaluation		End-of-season evaluation		Leaf area index
		Plant height	Biomass	Plant height	Biomass	
Replication	2	216.28^{ns}	4689.4^{ns}	121.69^{ns}	1198.7^{ns}	0.092^{ns}
Mulch type	5	1689.77^{**}	706775.6^{**}	3205.12^{**}	965034.8^{**}	17.11^{**}
Weed control	2	45.05^{ns}	287042.8^{**}	237.20^{*}	277574.3^{**}	3.79^{**}
Mulch type × Weed control	10	507.58^{**}	260759.3^{**}	1017.88^{**}	20260.5^{**}	5.86^{**}
Error	34	54.78	4447.02	50.70	7083.28	0.06
CV (%)		14.13	17.54	11.39	20.53	17.48

SOV, sources of variations; DF, degrees of freedom; MS, mean squares

ns not significant at the 0.05 level of probability. * and ** significantly different at the 0.05 and 0.01 levels of probability, respectively

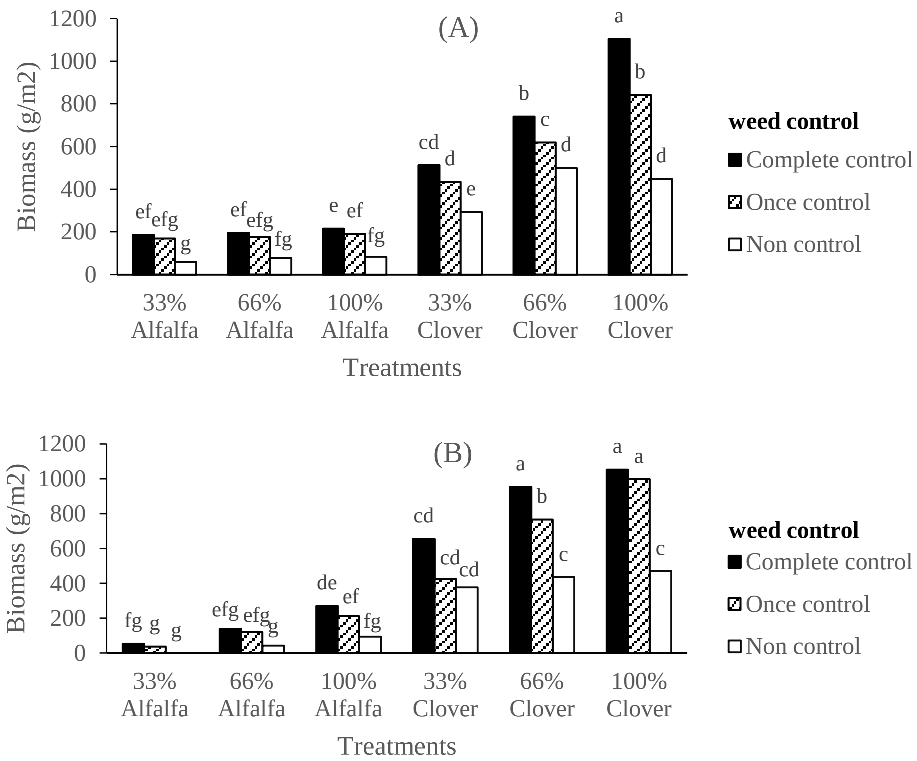

Fig. 1. Interaction effects of mulch type × weed control on biomass (A: mid-season and B: end-of-season evaluations). Mean values sharing similar letter(s) were not significant at $P \leq 0.05$, according to Duncan's multiple range tests.

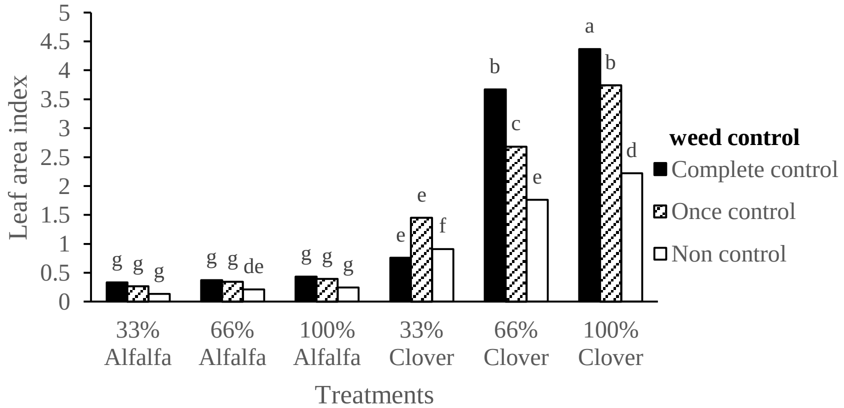

Fig. 2. Interaction effects of mulch type × weed control on leaf area index. Mean values sharing similar letter(s) are not significant at $P \leq 0.05$, according to Duncan's multiple range tests.

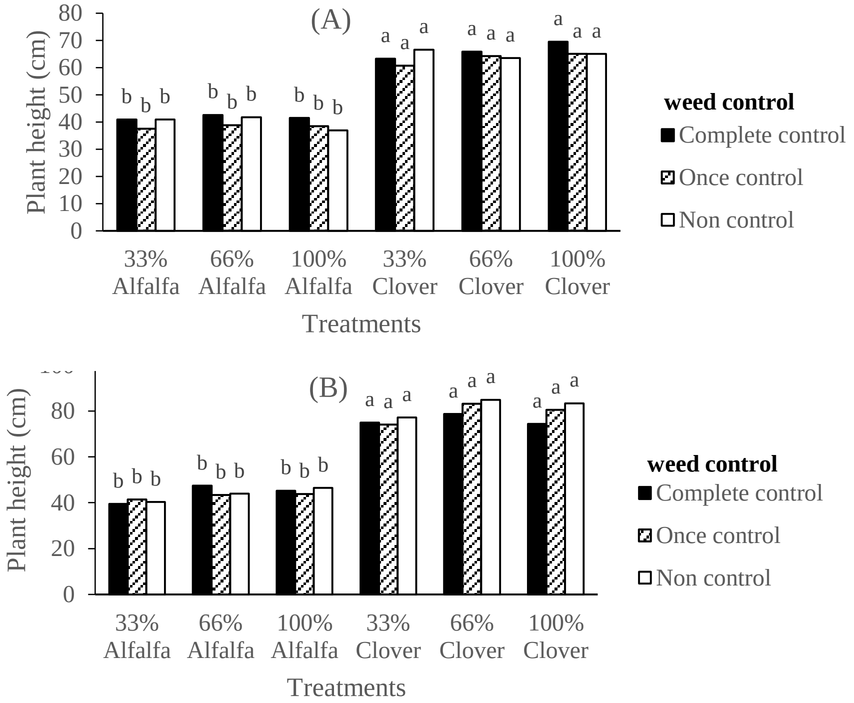

Fig. 3. Interaction effects of mulch type × weed control on plant height (A: mid-season and B: end-of-season evaluations). Mean values sharing similar letter(s) are not significant at $P \leq 0.05$, according to Duncan's multiple range tests.

Evaluation of the Traits of Weeds

Density of Broad-leaved and Narrow-leaved Weeds

At both mid-season and end-of-season stages, the density of narrow-leaved weeds was not affected by different mulch type and weed control (Table 5). However, the density of broad-leaved weeds at the mid-season evaluation was significantly affected by mulch type, weed control, and mulch type × weed control effects (Table 5). Also, the density of broad-leaved weeds at the end-of-season evaluation was significantly affected by mulch type and mulch type × weed control effects (Table 5).

At the mid-season evaluation, the highest density of broad-leaved weeds (31.33 plant m^{-2}) was related to the planting ratio of 33 % alfalfa under non-weed control conditions (Fig. 4A). However, the density of broad-leaved weeds of 33 % alfalfa under non-weed control conditions was not significantly different from the density of broad-leaved weeds of 33 % clover under non-weed control conditions (Fig. 4A). The lowest density of broad-leaved weeds was observed in 100 % clover under once-weed control conditions (Fig. 4A). However, the density of broad-leaved weeds of 100 % clover under once-weed control conditions was not significantly different from the density of broad-leaved weeds of 33 %, 66 % and 100 % alfalfa, 33 % and 66 % clover, wheat straw mulch and non-mulched treatment under once-weed control conditions and 100 % alfalfa, 100 % clover and non-mulched treatment under non-weed control conditions (Fig. 4A).

At the end-of-season evaluation, the highest density of broad-leaved weeds (29 plant m^{-2}) was related to the planting ratio of 33 % alfalfa under once-weed control conditions (Fig. 4B). However, the density of broad-leaved weeds of 33 % alfalfa under once-weed control conditions was not significantly different from the density of broad-leaved weeds of 33 % alfalfa under non-weed control conditions, 66 % and 100 % alfalfa under once-weed and non-weed control conditions, 66 % clover under non-weed control conditions, wheat straw mulch under non-weed control conditions and non-mulched treatment under once-weed and non-weed control conditions (Fig. 4B). The lowest density of broad-leaved weeds was observed in 100 % clover under once-weed control conditions (Fig. 4B). However, the density of broad-leaved weeds of 100 % clover under once-weed control conditions was not significantly different from the density of broad-leaved weeds of 66 % alfalfa under once-weed control conditions, 33 % and 66 % clover under once-weed and non-weed control conditions, 100 % clover under non-weed control conditions and wheat straw mulch under once-weed and non-weed control conditions (Fig. 4B).

It has been shown that the effect of cover crops on weed control depends on the rapid development of cover crops and its duration of shading (Ekeleme et al., 2003). Clover prevented germination and weed growth due to its higher leaf area index, dry weight and height than alfalfa. These characteristics cause that if the weed seeds germinate, the light needs for the weeds will not be provided and they will not grow enough and consequently will not cause much damage. Insufficient light supply in weeds reduces their photosynthetic power and due to insufficient vegetative growth, they do not enter the reproductive phase and do not produce seeds. These factors cause in addition to controlling weeds in the same year, fewer weeds will grow in subsequent years due to reduced seed production in the seed bank.

Density of Total Weeds

The density of total weeds at the mid-season evaluation was significantly affected by weed control and mulch type × weed control effects (Table 5). Also, the density of total weeds at the end-of-season evaluation was significantly affected by mulch type and mulch type × weed control effects (Table 5). The highest density of total weeds at the mid-season evaluation was related to the planting ratio of 33 % alfalfa under non-weed control conditions which was not significantly different from 33 % alfalfa under once-weed control conditions, 66 % alfalfa under once-weed control and non-weed control conditions, 100 % alfalfa under non-weed control conditions, 33 %, 66 % and 100 % clover under non-weed control conditions, wheat straw mulch under non-weed control conditions and non-mulched treatment under once-weed control and non-weed control conditions (Fig. 5A). The highest density of total weeds at the end-of-season evaluation was related to the planting ratio of 33 % alfalfa under once-weed control conditions which was not significantly different from 33 % alfalfa under non-weed control conditions, 66 % and 100 % alfalfa under once-weed control and non-weed control conditions, 66 % clover under non-weed control conditions, wheat straw mulch under non-weed control conditions and non-mulched treatment under once-weed control and non-weed control conditions (Fig. 5B). At both stages, the lowest density of total weeds was observed in 100 % clover under once-weed control conditions (Fig. 5 A and B).

Increasing the density of weeds in the absence of using mulch indicated the usefulness of using mulch in the form of wheat straw (non-living mulch) and clover (living mulch). The lack of significant changes in weed density in alfalfa plots showed that the cultivation of alfalfa as a living mulch was not effective in weed control. The reason for this was poor growth and lack of proper canopy cover by alfalfa plants. In other words, in competition between plant species, weeds were stronger competitors than alfalfa. In the plots where the clover was grown as a cover crop, clover had a predominance over the weeds due to its faster growth and development. The use of wheat straw mulch limited the growth of weeds through shading. Also, the lack of uniform distribution of weeds in the field increased the density of the weeds in the planting ratio of 33 % alfalfa.

Biomass of Broad-leaved and Narrow-leaved Weeds

The biomass of broad-leaved weeds at both mid-season and end-of-season evaluations was significantly affected by mulch type, weed control, and mulch type × weed control effects, while the biomass of narrow-leaved weeds was not affected by them (Table 5). Both wheat straw and living mulches reduced the biomass of broad-leaved weeds compared to non-mulched treatment. In this regard, at the mid-season stage, the highest biomass of broad-leaved weeds (576 g m^{-2}) was observed in the non-mulched treatment under non-weed control conditions which was not significantly different from 33 % alfalfa under non-weed control conditions. At the end-of-season stage, the highest biomass of broad-leaved weeds (1069 g m^{-2}) was observed in the non-mulched treatment under non-weed control conditions (Fig. 6 A and B). At the mid-season stage, the lowest biomass of broad-leaved weeds (48 g m^{-2}) was observed in 100 % clover under once-weed control conditions which were not significantly different from all other treatments except non-mulched and 33 % alfalfa treatments under non-weed control (Fig. 6A). Also, at the end-of-season stage, the lowest biomass of broad-leaved weeds (51 g m^{-2}) was observed in 100 % clover under once-weed control conditions which were not significantly different from 33 %, 66 %, and 100 % alfalfa, 33 % and 66 % clover, wheat straw mulch, non-mulched treatment under once-weed control conditions and wheat straw mulch under non-weed control conditions (Fig. 6B).

Biomass of Total Weeds

The biomass of total weeds at both mid-season and end-of-season evaluations was significantly affected by mulch type, weed control, and mulch type × weed control effects (Table 5). At the mid-season stage, the highest biomass of total weeds (578 g m^{-2}) was observed in the non-mulched treatment under non-weed control conditions which was not significantly different from 33 % alfalfa under non-weed control conditions. At the end-of-season stage, the highest biomass of total weeds (1101 g m^{-2}) was observed in the non-mulched treatment under non-weed control conditions (Fig. 7 A and B). These results indicated that the use of mulch, except 33 % alfalfa at mid-season under non-weed control conditions, seems to have positive effects on weed control.

Table 5. Analysis of variance for different traits including the density and biomass of narrow-leaved, broad-leaved and total weeds.

SOV	DF	MS											
		Mid-season evaluation			End-of-season evaluation			Mid-season evaluation			End-of-season evaluation		
		Density of narrow-leaved weeds	Density of broad-leaved weeds	Density of total weeds	Density of narrow-leaved weeds	Density of broad-leaved weeds	Density of total weeds	Biomass of narrow-leaved weeds	Biomass of broad-leaved weeds	Biomass of total weeds	Biomass of narrow-leaved weeds	Biomass of broad-leaved weeds	Biomass of total weeds
Replication	2	38.59^{ns}	42.74^{ns}	13.03^{ns}	4.89^{ns}	327.63*	410.66*	519.35^{ns}	36067.90^{ns}	35133.98^{ns}	748.11^{ns}	159161.71*	181215.87*
Mulch type	7	9.67^{ns}	98.9*	98.74^{ns}	2.55^{ns}	295.64**	331.72**	202.51^{ns}	47373.44**	46186.12*	396.11^{ns}	161080.67**	174087.77**
Weed control	1	49.38^{ns}	630.04**	1230.9**	0.75^{ns}	114.86^{ns}	96.51^{ns}	515.26^{ns}	401456.9**	445618.39**	388.91^{ns}	2098828.31**	2156290.26**
Mulch type × Weed control	7	16.55^{ns}	104.39**	143.95*	1.63^{ns}	168.82*	187.66*	272.22^{ns}	56312.89**	58387.71**	328.73^{ns}	247370.90**	260022.44**
Error	26	13.89	38.73	66.39	2.43	66.25	78.72	281.3	19880.93	19997.38	395.24	21609.99	22285.05
CV (%)		31.61	37.74	33.61	39.07	39.46	31.66	35.22	38.66	36.78	33.68	39.06	39.10

SOV, sources of variations; DF, degrees of freedom; MS, mean squares

ns not significant at the 0.05 level of probability. * and ** significantly different at the 0.05 and 0.01 levels of probability, respectively

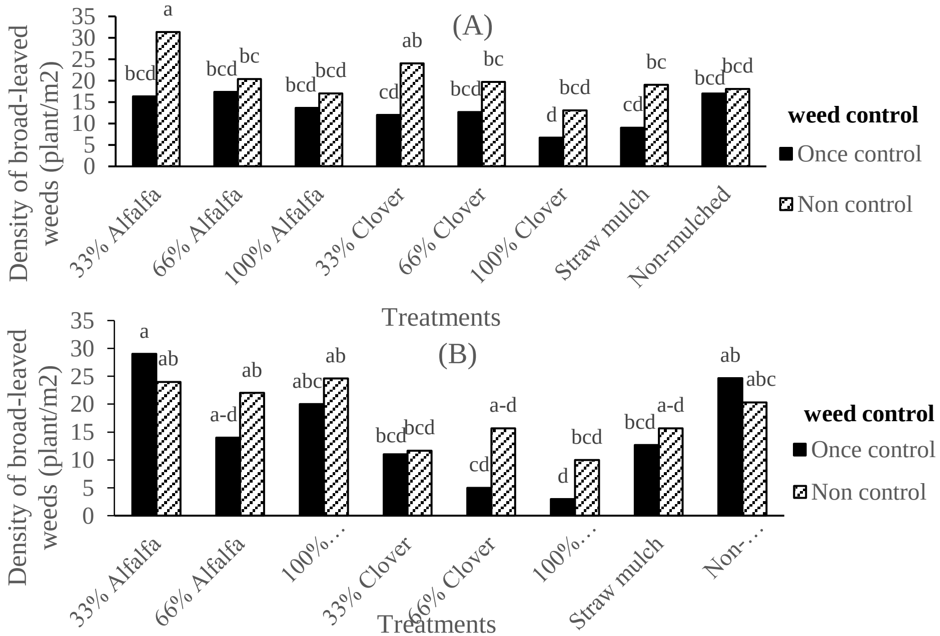

Fig. 4. Interaction effects of mulch type × weed control on the density of broad-leaved weeds (A: mid-season and B: end-of-season evaluations). Mean values sharing similar letter(s) are not significant at $P \leq 0.05$, according to Duncan's multiple range tests.

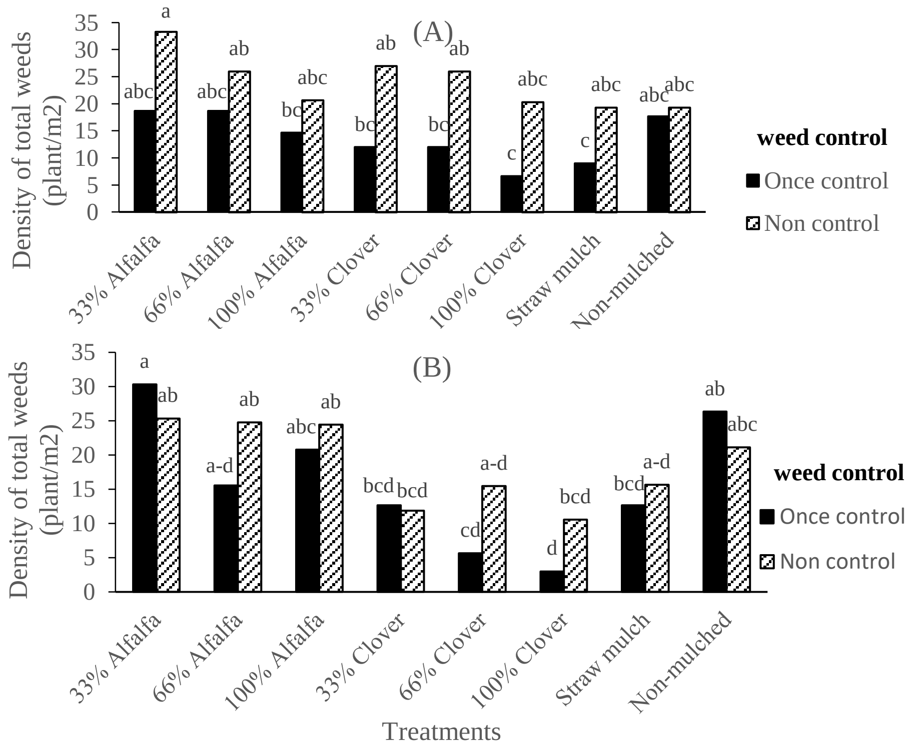

Fig. 5. Interaction effects of mulch type × weed control on the density of total weeds (A: mid-season and B: end-of-season evaluations). Mean values sharing similar letter(s) are not significant at $P \leq 0.05$, according to Duncan's multiple range tests.

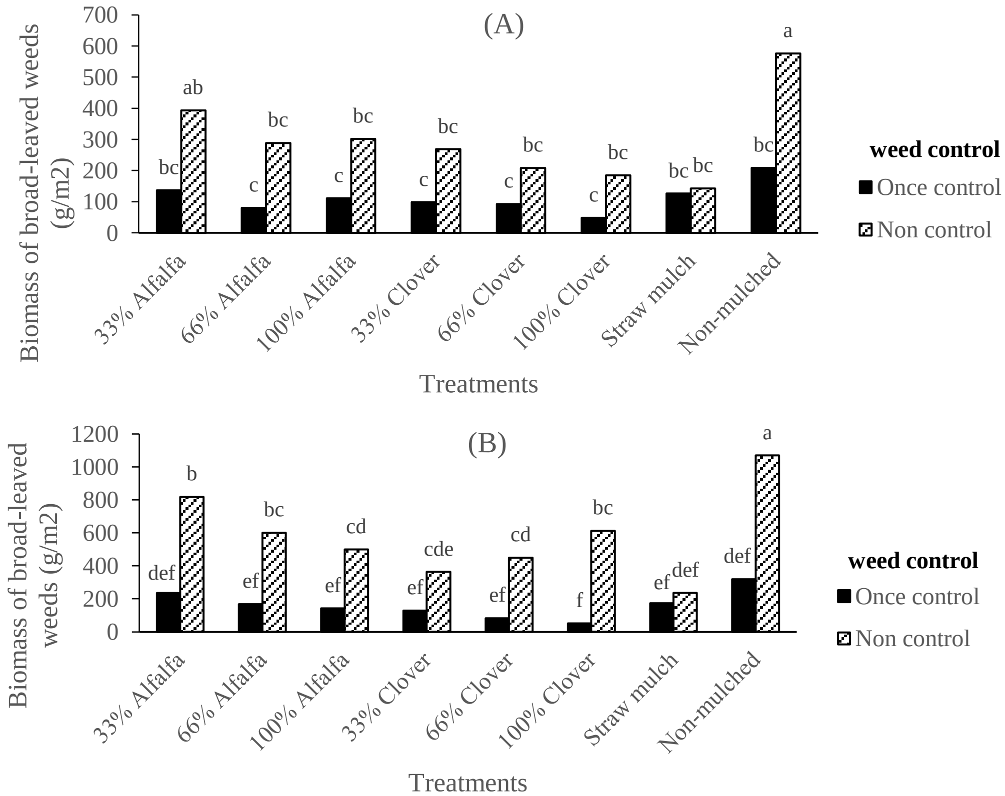

Fig. 6. Interaction effects of mulch type × weed control on the biomass of broad-leaved weeds (A: mid-season and B: end-of-season evaluations). Mean values sharing similar letter(s) are not significant at $P \leq 0.05$, according to Duncan's multiple range tests.

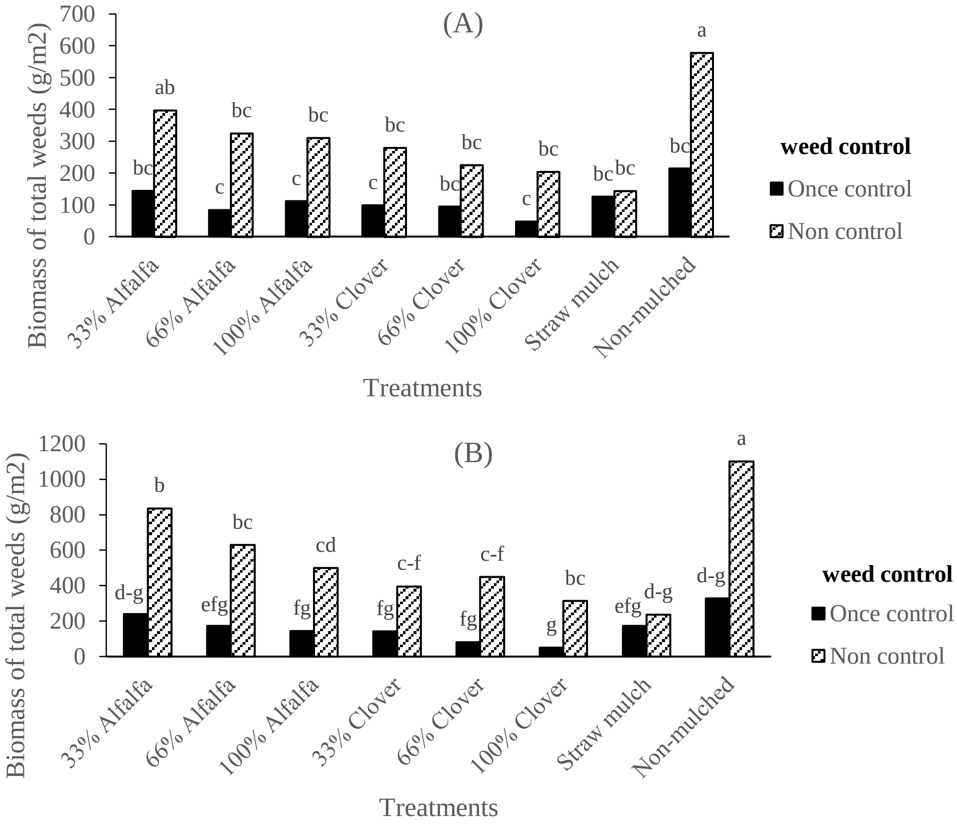

Fig 7. Interaction effects of mulch type × weed control on the biomass of total weeds (A: mid-season and B: end-of-season evaluations). Mean values sharing similar letter(s) are not significant at $P \leq 0.05$, according to Duncan's multiple range tests.

The presence of living mulch, especially clover, had a great effect on reducing weeds biomass, which could be due to shading or competition of living mulch with weeds. On the other hand, the production and secretion of allopathic compounds by clover roots in the soil may have a deterrent effect on germination and the growth and development of weeds. Some researchers have cited the prevention of weeds growth and reduced dry matter production as a result of the competitive or allopathic effects of cover crops (Randhawa et al., 2002). Researchers also stated that weed control is a result of the allopathic effect of cover crops in addition to their competition (Vasilakoglou et al., 2006).

The reason for the optimal control of weeds by clover and the relatively less effect of alfalfa on them can be related to the allopathic ability of clover and also the rapid growth and development of foliage and the creation of smothering conditions by this plant, as mentioned in the section of living mulch traits of this study and also reported by other researchers (Barberi and Mazzoncini, 2001; Qasem and Foy, 2001). It can also be said that the slow growth of alfalfa caused the biomass of alfalfa to be less than clover in all treatments. Therefore, alfalfa could not have more effective control over weeds due to less canopy and insufficient soil cover. Despite this, it can be concluded that the use of mulch was generally effective in controlling weeds.

Wheat straw mulch had the lowest weed biomass under non-weed control conditions. Therefore, it seems that soil covered with wheat straw has been more effective in controlling weeds than living mulch. The reason for this can be considered the elimination of the third species (living mulch) from the competition between crops, weeds and living mulches. Wheat straw mulch also prevents the growth of weeds by creating shade on the seeds of weeds.

Evaluation of the traits of coriander

It should be noted that due to the complete elimination and destruction of coriander seedlings at 66 and 100 % clover, the resulting data of these treatments in all evaluated traits were equal to zero and were not included in the analysis.

Number of Sub-branches

The number of sub-branches was significantly affected by weed control and mulch type × weed control effects (Table 6). The highest number of sub-branches was observed in wheat straw mulch, 33 % and 100 % alfalfa treatments under complete weed control conditions which were not significantly different from all other treatments except non-mulched, 33 % clover and 66 % alfalfa treatments under non-weed control conditions (Fig. 8). Non-weed control conditions in all treatments reduced the number of sub-branches compared to complete and once-weed control conditions (Fig. 8). These reductions were significant in some treatments and non-significant in some other treatments (Fig. 8). Once-weed control also had positive effects in all treatments, so that the reduction in the number of sub-branches was not significant compared to complete weed control conditions (Fig. 8).

Table 6. Analysis of variance for different traits including yield components, grain yield, biomass yield, harvest index, percentage and yield of essential oil of coriander.

SOV	DF	MS										
		Number of sub-branches	Number of umbels per plant	Number of umbelets per umbel	Number of seeds per umbel	Number of seeds per umbelets	1000 seeds weight	Grain yield	Biomass yield	Harvest index	Percentage of essential oil	Yield of essential oil
Replication	2	0.32^{ns}	3.09^{ns}	0.36^{ns}	4.51^{ns}	0.22^{ns}	0.02^{ns}	7844.8^{*}	57426.08^{ns}	53.65^{ns}	0.0003^{ns}	0.11^{ns}
Mulch type	5	2.07^{ns}	128.56^{**}	3.61^{**}	158.01^{**}	9.59^{**}	0.44^{ns}	1031853.06^{**}	6616345.8^{**}	201.41^{**}	0.001^{ns}	3.75^{**}
Weed control	2	15.49^{**}	257.43^{**}	3.83^{**}	488.56^{**}	10.58^{**}	0.93^{*}	3077401.11^{**}	11212147.51^{**}	943.07^{**}	0.00009^{ns}	12.68^{**}
Mulch type × Weed control	10	2.53^{*}	70.15^{**}	1.75^{**}	127.60^{**}	5.24^{**}	0.40^{ns}	755040.9^{**}	3447136.32^{**}	199.07^{**}	0.0008^{ns}	2.94^{**}
Error	34	1.11	5.26	0.31	6.46	0.51	0.22	19961.2	87956.69	43.90	0.001	0.25
CV (%)		17.82	13.65	14.31	15.55	17.33	7.46	18.27	13.05	20.34	16.14	31.89

SOV, sources of variations; DF, degrees of freedom; MS, mean squares

ns not significant at the 0.05 level of probability. * and ** significantly different at the 0.05 and 0.01 levels of probability, respectively

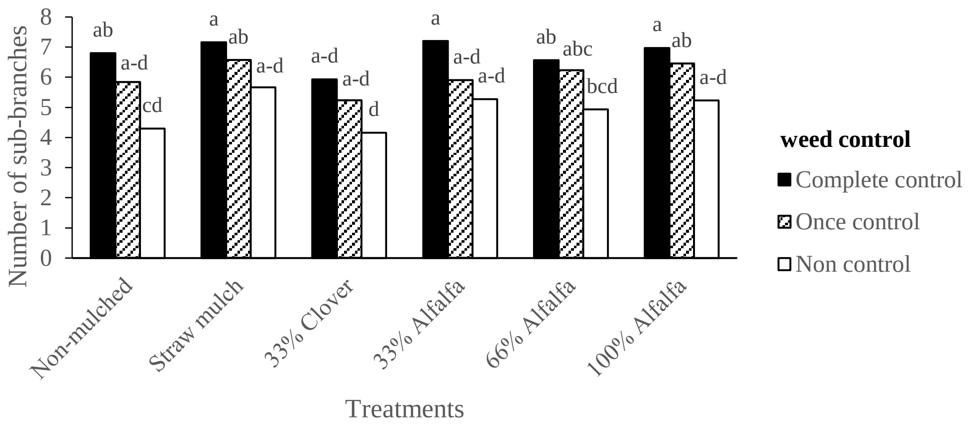

Fig. 8. Interaction effects of mulch type × weed control on number of sub-branches of coriander. Mean values sharing similar letter(s) are not significant at $P \leq 0.05$, according to Duncan's multiple range tests.

It is supposed that in the complete and once-weed control plots, coriander plants have been able to effectively use environmental factors and have expanded their branches, due to the elimination of competition with weeds. In the non-weed control conditions, less production of sub-branches might be related to the competition for light, water and food between the crop and weeds, and the superiority of the weeds in allocating the mentioned resources for their growth and creating a shortage for the crop.

Number of Umbels per Plant and Umbelets per Umbel

The number of umbels per plant and umbelets per umbel was significantly affected by mulch type, weed control, and mulch type × weed control effects (Table 6). Wheat straw mulch under complete weed control conditions (with an average of 24.8) had the highest number of umbels per plant (Fig. 9A). However, there was no significant difference in the number of umbels per plant in wheat straw mulch treatment between complete weed control and once-weed control conditions (Fig. 9A). The highest number of umbelets per umbel (with an average of 4.99) was obtained from non-mulched treatment under complete weed control conditions (Fig. 9B). However, the number of umbelets per umbel of non-mulched treatment under complete weed control conditions was not significantly different from the number of umbelets per umbel of non-mulched treatment under once-weed control conditions, 33 % alfalfa under complete and once-weed control conditions, 66 % alfalfa under all weed control conditions and 100 % alfalfa under complete weed control conditions (Fig. 9B). 33 % clover under non-weed control conditions (with averages of 6.5 and 2.09, respectively) had the lowest number of umbels per plant and number of umbelets per umbel (Fig. 9 A and B).

Considering that the number of umbels per plant and umbelets per umbel in all treatments of alfalfa was more than clover, so alfalfa was superior to clover in these traits as an important part of yield components. Non-weed control conditions reduced the number of umbels per plant and umbelets per umbel. One possible reason in this regard is to have a suitable space to increase the number of sub-branches in the absence of weeds, which ultimately led to optimal growth and increased the number of umbels per plant and umbelets per umbel. The number of umbels per plant and umbelets per umbel mainly depends on the factors, especially nutrients and sufficient moisture, that are suitable for the rapid growth of the plant (Dahiya et al., 2007). Nutrients and moisture as well as light intake are significantly reduced by increasing weed interference. These limitations in the reproductive stages of the plant, by reducing the current photosynthesis, reduce the plant's ability to allocate photosynthetic materials to produce reproductive units and ultimately lead to a reduction in the number of umbels per plant and umbelets per umbel. The number of umbels in the plants of umbellifers family is one of the main components and determines the final performance because the number of umbels determine the final number of umbelets and seeds.

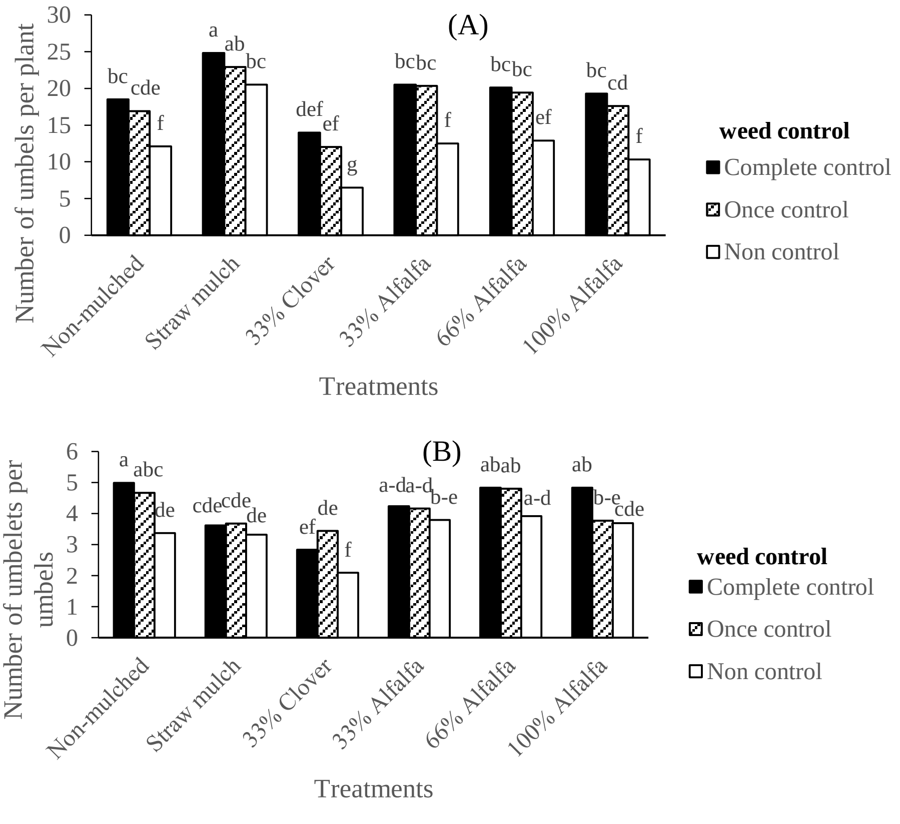

Fig. 9. Interaction effects of mulch type × weed control on the number of umbels per plant (A) and number of umbelets per umbel (B) of coriander. Mean values sharing similar letter(s) are not significant at $P \leq 0.05$, according to Duncan's multiple range tests.

Number of Seeds per Umbel and Umbelet

The number of seeds per umbel and umbelet was significantly affected by mulch type, weed control, and mulch type × weed control effects (Table 6). The highest number of seeds per umbel (with averages of 27.77 and 26.76, respectively) was observed in 33 % alfalfa and non-mulched treatment, respectively, both of them under complete weed control conditions (Fig. 10A). However, there was no significant difference in the number of seeds per umbel between the aforementioned treatments and wheat straw mulch under complete and once-weed control conditions (Fig. 10A). Also, 33 % clover treatment under non-weed control conditions (with an average of 5.98 seeds per umbel) had the lowest number of seeds per umbel (Fig. 10A). However, there was no significant difference between 33 % clover and 33 % alfalfa treatments under non-weed control conditions (Fig. 10A). Wheat straw mulch under complete and once-weed control conditions (with averages of 7.01 and 6.77, respectively) had the highest number of seeds per umbelet which was not significantly different from33 % alfalfa under complete weed control conditions (Fig. 10B). Also, 66 % alfalfa under non-weed control conditions (with an average of 2.51) had the lowest number of seeds per umbelet which was not significantly different from wheat straw mulch under non-weed control conditions, 33 % clover under all weed control conditions, 33 % alfalfa under once-weed and non-weed control conditions, 66 % alfalfa under complete and once-weed control conditions and 100 % alfalfa under complete and non-weed control conditions (Fig. 10B).

The high number of seeds per umbel and umbelet in the weed control plots can be due to reduce weed density and thus reduce competition between species and proper distribution of radiation in the plant canopy as stated by Majid et al. (2003). In the non-weed control conditions, the competitive pressure due to the presence of weeds was higher and weakened the crop. As a result, the plant could not effectively benefit from environmental factors, especially nutrients, to improve growth and increase yield. Comparing the different types of mulches, it was found that the use of alfalfa and clover not only did not have a beneficial effect on the number of seeds per umbel and umbelet of coriander but also reduced the amount of these traits, compared to the wheat straw mulch and non-mulched treatments. The reduction of alfalfa to 33 % caused some mitigation of the negative effects of alfalfa on coriander. It seems that high densities of alfalfa caused competition over food resources and space used by the two plants. The number of seeds per umbel and umbelet is an important trait that has a direct effect on grain yield. Results of grain yield and biomass production also showed the negative effects of increasing alfalfa density (Fig. 11 A and B). Therefore, reducing the number of seeds per umbel and umbelet due to increasing alfalfa density eventually led to a decrease in grain yield.

1000 Seeds' Weight

The 1000 seeds' weight was significantly affected by weed control, but the effect of using mulches on the weight of 1000 seeds was not significant (Table 6). The highest and lowest 1000 seeds' weight were observed in complete weed control and non-weed control conditions, respectively (Fig. 12). In once-weed control conditions, 1000 seeds' weight was not significantly different compared to the complete weed control conditions (Fig. 12).

Low 1000 seeds' weight in non-weed control conditions can be due to competitive conditions between crops and weeds that affect the number of fertile flowers and the distribution of photosynthetic materials, and less photosynthetic material is available to the seeds. Therefore, in non-weed control conditions, the weight of the coriander seeds and their size decreased. Coriander has probably been able to direct more photosynthetic materials to the seeds and increase the weight of the seeds by utilizing favorable environmental resources in the conditions of complete or partial removal of weeds.

Grain Yield and Biomass Production

The grain yield and biomass production were significantly affected by mulch type, weed control, and mulch type × weed control effects (Table 6). The highest grain yield was observed using wheat straw mulch under complete and once-weed control conditions (1601.4 and 1517.0 kg ha^{-1}, respectively) and also 33 % alfalfa under complete weed control conditions (1562.0 kg ha^{-1}) (Fig. 11A). However, they had no significant difference with non-mulched treatment under complete weed control conditions (Fig. 11A). Clover (33 %) under non-weed control conditions showed the lowest grain yield (Fig. 11A). However, the grain yield of 33 % clover treatment under non-weed control conditions was not significantly different from the grain yield of the same treatment under complete and once-weed control conditions and also from the grain yield of non-mulched and 33 % and 100 % alfalfa treatments under non-weed control conditions (Fig. 11A). Performing once-weed control in the wheat straw mulch treatment minimized the yield reduction due to weed interference in this treatment, so that it did not show a significant difference with the complete weed control conditions (Fig. 11A).

The highest biomass yields were observed using wheat straw mulch as well as 33 % alfalfa under complete weed control conditions (3901.0 and 3675.0 kg ha^{-1}, respectively) and wheat straw mulch under once-weed control conditions (3416.0 kg ha^{-1}) (Fig. 11B). Clover (33 %) under non-weed control conditions showed the lowest biomass yield (Fig. 11B). However, the biomass yield of 33 % clover under non-weed control conditions was not significantly different from the biomass yield of 33 % clover under once-weed control conditions (Fig. 11B). So, results showed the negative effects of using 33 % clover on coriander grain and biomass yields compared to those of non-mulched treatment (Fig. 11 A and B). Also, non-weed control conditions caused a significant reduction in grain and biomass yields of all treatments compared to those of corresponding treatments under complete and once-weed control conditions (Fig. 11 A and B).

Increasing the density of alfalfa from 33 % to 100 % under complete weed control conditions reduced the coriander grain yield and biomass production (Fig. 11 A and B). It seems that with the increase in alfalfa density, the competition between alfalfa and coriander has increased. Also, the number of seeds per umbel and umbelet decreased at densities above 33 % of alfalfa under complete weed control conditions, so the coriander grain yield decreased at these densities.

In this study it was shown that clover not only did not have a positive effect on increasing the yield of coriander but also had negative effects on the coriander. This was determined by comparing grain yield and biomass production in the absence of mulch with the planting ratio of 33 % clover (Fig. 11 A and B). In this regard, we can mention the faster and wider coverage of the aerial part of clover than coriander. Clover had a predominant and suffocating effect on coriander due to higher plant height, leaf area index and biomass yield (as expressed in the section of living mulch traits). So, in high clover planting ratios (66 and 100 %), it is supposed that coriander used fewer resources and the yield components and the amount of material accumulation in coriander seeds decreased so that the coriander grain yield and biomass production were equal to zero.

In addition to the distribution of clover foliage, the allopathic effects of clover root can also be considered in the effects of clover dominance on coriander. Among cover crops, extensive research on the potential of allelopathy and the production of allelochemicals in clover has been proven (Ohno et al., 2000). Clover has been reported to produce volatile compounds that inhibit the germination and growth of several weed species (Barberi and Mazzoncini, 2001; Qasem and Foy, 2001). It has been shown that the morphological, physiological and biochemical characteristics of a highly competitive crop enable it to be conquered using resources more efficiently than other less competitive crops (Lemerle et al., 1996). In the present study, the extent of clover foliage and vegetation compared to coriander was well evident. So, clover at densities of 66 % and 100 % caused suffocation and complete destruction of coriander seedlings.

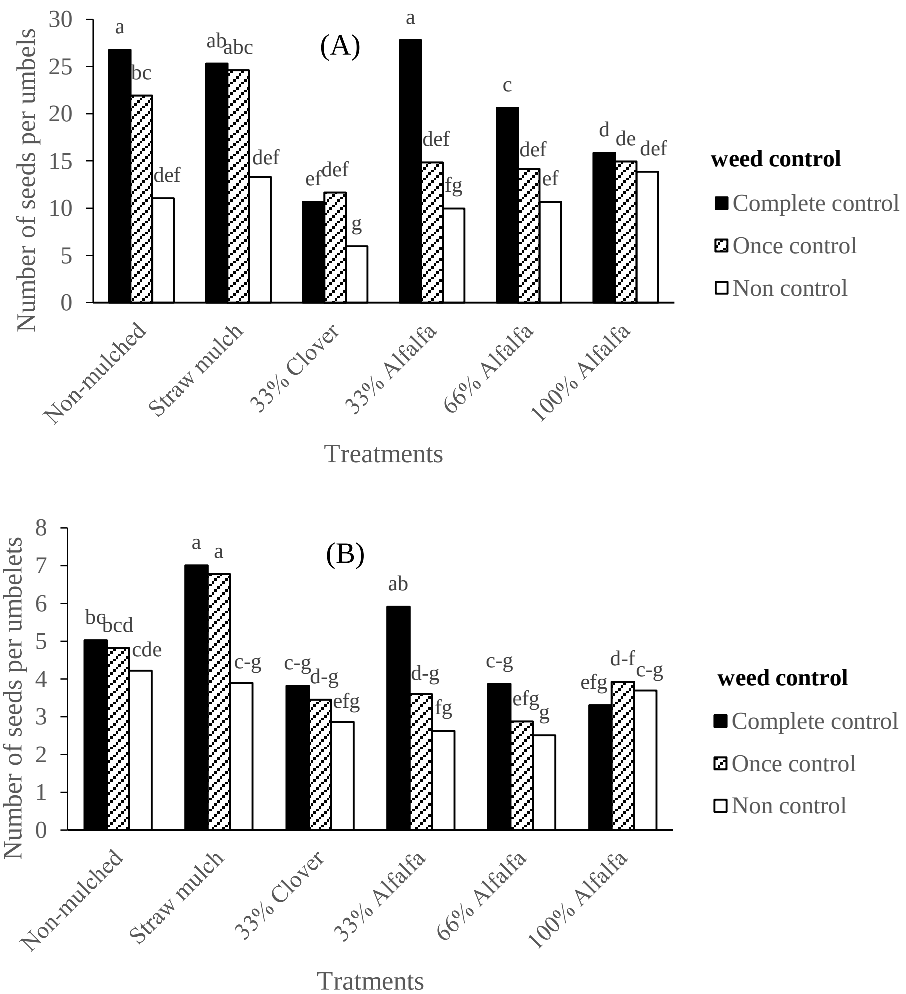

Fig. 10. Interaction effects of mulch type × weed control on the number of seeds per umbel (A) and the number of seeds per umbelets (B) of coriander. Mean values sharing similar letter(s) are not significant at $P \leq 0.05$, according to Duncan's multiple range tests.

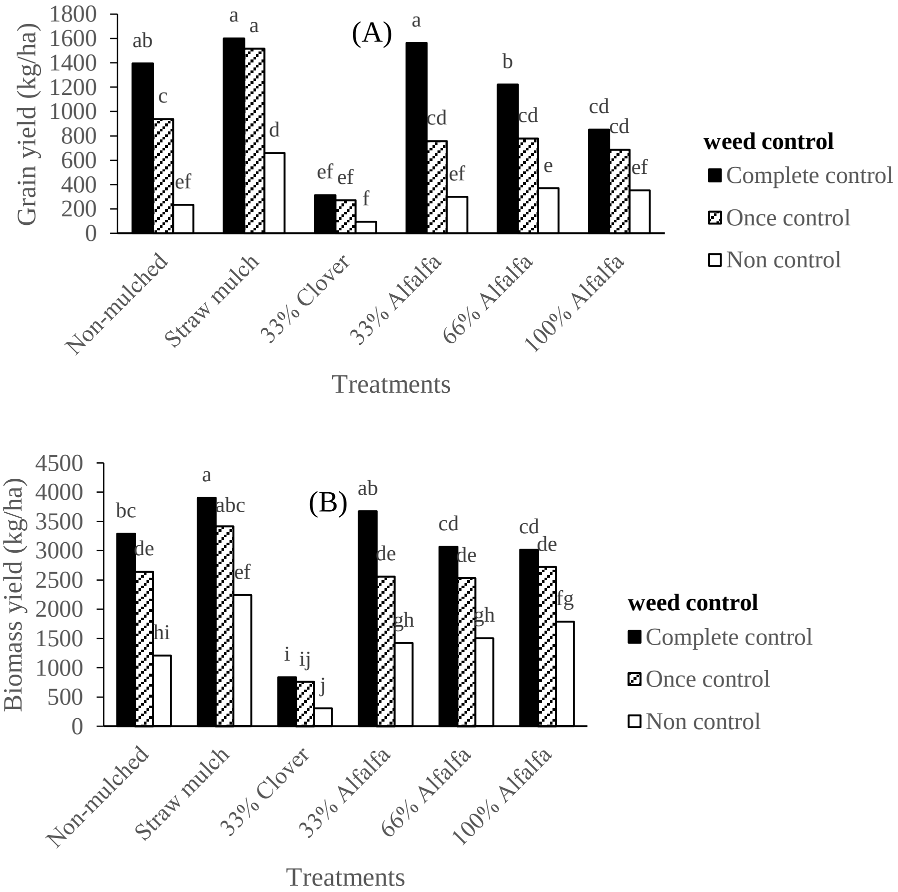

Fig.11. Interaction effects of mulch type × weed control on grain yield (A) and biomass yield (B) of coriander. Mean values sharing similar letter(s) are not significant at $P \leq 0.05$, according to Duncan's multiple range tests.

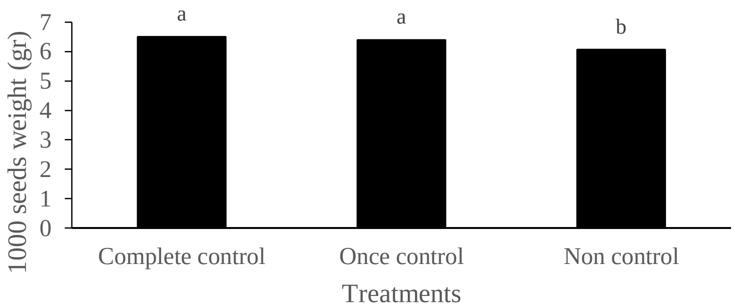

Fig. 12. Mean comparison for the effect of weed control on 1000 seeds weight of the coriander. Mean values sharing similar letter(s) are not significant at $P \leq 0.05$, according to Duncan's multiple range tests.

High grain yield using wheat straw mulch compared to living mulches can be due to the surface cover created by wheat straw. In this case wheat straw mulch prevents the germination and growth of weed seeds through shading. Since wheat straw mulch, unlike living mulches, has no competition with crops, so by using wheat straw, the competition due to the presence of the second crop is eliminated and more moisture and nutrients are provided to the crop. Since water is a poor conductor of heat compared to soil (Lehrman, 1998), the presence of wheat straw mulch increased the water content in the soil and thus reduced its temperature. Researchers also reported that straw mulch was effective at conserving soil moisture, suppressing the growth of weed flora, promoting root development and thereby improving the grain yield of wheat (*Triticum aestivum* L.) (Rahman et al., 2005).

Non-weed control conditions caused a severe decline in grain yield and biomass production in all treatments, indicating the presence of weeds interfering with the crop. It seems that resource limitation at different growth stages has reduced leaf area, light absorption, current photosynthesis and synthesis of materials, resulting in reduced biomass accumulation.

Harvest Index

The harvest index was significantly affected by mulch type, weed control, and mulch type × weed control effects (Table 6). The highest harvest index was observed in wheat straw mulch under once-weed control conditions

(Fig. 13). However, no significant differences ($P \leq 0.05$) were observed between the harvest index of this treatment and those from all treatments under complete weed control and once-weed control conditions except the harvest index of 100 % alfalfa treatment (Fig. 13). Due to weed interference in the non-weed control conditions, harvest index decreased in the non-weed control conditions of all treatments compared to those of once-weed control and complete weed control conditions of their corresponding treatments (Fig. 13). In alfalfa mulch treatments with increasing alfalfa density under complete weed control conditions, the harvest index decreased so that, in 100 % alfalfa treatment, a smaller harvest index was observed compared to those of other alfalfa densities (Fig. 13) . The decrease in harvest index in 100 % alfalfa treatment can be due to the fact that in 100 % alfalfa treatment, grain yield had a greater reduction than that of biomass yield (Fig. 11 A and B, respectively).

Essential Oil Percentage and Yield

The percentage of essential oil was not affected by mulch type and weed control (Table 6). While the yield of essential oil was significantly affected by mulch type, weed control, and mulch type × weed control effects (Table 6). The results showed the positive effect of using wheat straw mulch on essential oil yield (Fig. 14), so that he highest yield of coriander essential oil (3.35 kg ha^{-2}) was obtained from wheat straw mulch under complete weed control conditions (Fig. 14). However, the yield of coriander essential oil of this treatment was not significantly different from the yield of coriander essential oil of the same treatment under once-weed control conditions and also from the yield of coriander essential oil of the non-mulched and 33 % alfalfa treatments under complete weed control conditions (Fig. 14). The lowest yield of coriander essential oil was observed at 33 % clover under non-weed control conditions which were not significantly different from those of the same treatment under complete and once-weed control conditions and also from those of all other treatments, except straw mulch treatment, under non-weed control conditions (Fig.14). Since the yield of essential oil is a function of the percentage of essential oil and the economic yield of the plant, therefore, an increase or decrease in either of these two causes a change in the yield of the essential oil of the plant. Due to the fact that in the present study, the percentage of measured essential oil did not show significant changes, so the results of essential oil yield were completely proportional to the results of grain yield (Fig. 11A).

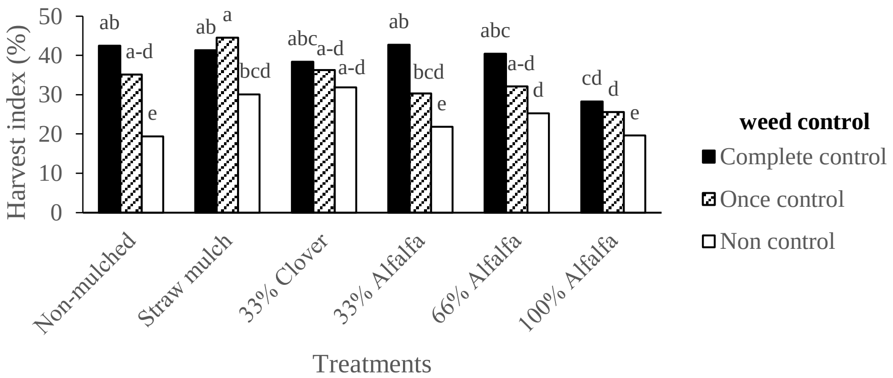

Fig 13. Interaction effects of mulch type × weed control on harvest index of coriander. Mean values sharing similar letter(s) are not significant at $P \leq 0.05$, according to Duncan's multiple range tests.

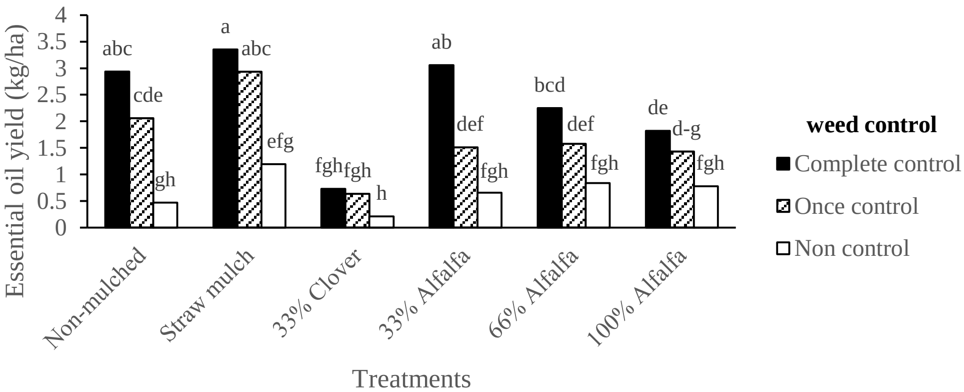

Fig 14. Interaction effects of mulch type × weed control on essential oil yield of coriander. Mean values sharing similar letter(s) are not significant at $P \leq 0.05$, according to Duncan's multiple range tests.

CONCLUSIONS

Wheat straw as a non-living mulch reduced the density and biomass of broad-leaved weeds and field total weeds compared to non-mulched treatment. Also, the grain yield, biomass yield and essential oil yield of the main crop of this study i.e. coriander increased by increasing the number of umbels per plant and the number of seeds per umbelet in wheat straw mulch treatment. The density of a living mulch influences its competition with the main crop as well as its ability to provide weed control. Clover was more effective in controlling weeds than alfalfa, but it is not recommended due to its negative effects on coriander seedlings. Complete weed control caused a significant increase in all evaluated traits in coriander and conversely, non-weed control conditions caused a decrease in yield and yield components. This study showed that wheat straw mulch is a suitable solution to control coriander weeds, which not only does not interfere with the growth of coriander but also causes effective control of its weeds.

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بررسی استفاده از مالچ های زنده و غیر زنده در کنترل علــف هــای هرز گشنیز (*Coriandrum sativum* L.)

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چکیده – علف‌های هرز مهم‌ترین عامل محدودکننده در سیستم‌های کشاورزی می‌باشند و استفاده از مالچ به‌عنوان راهکاری مناسب در مدیریت اکولوژیک علف‌های هرز در نظر گرفته می‌شود. به‌منظور بررسی عملکرد و کنترل علف‌های هرز گشنیز، آزمایشی به‌صورت فاکتوریل در مزرعه تحقیقاتی دانشکده کشاورزی دانشگاه زنجان در سال ۱۳۹۹ انجام شد. فاکتور اول، نوع مالچ شامل نسبت‌های ۱۰۰ درصد (۴۰ کیلوگرم در هکتار)، ۶۶ درصد (۲۶/۴ کیلوگرم در هکتار) و ۳۳ درصد (۱۳/۲ کیلوگرم در هکتار) شبدر (*Trifolium alexandrinum* L.) و ۱۰۰ درصد (۲۰ کیلوگرم در هکتار)، ۶۶ درصد (۱۳/۲ کیلوگرم در هکتار) و ۳۳ درصد (۶/۶ کیلوگرم در هکتار) یونجه (*Medicago scutellate* L.) به‌عنوان مالچ‌های زنده، کلش گندم (*Triticum aestivum* L.) (یک کیلوگرم در مترمربع) به‌عنوان مالچ غیرزنده و یک تیمار بدون مالچ و فاکتور دوم، کنترل علف‌های هرز شامل کنترل کامل علف‌های هرز، یکبار وجین علف‌های هرز و عدم کنترل علف‌های هرز بود. نتایج نشان داد که تیمارهای نوع مالچ و کنترل علف‌های هرز بر اجزای عملکرد و عملکرد گشنیز از نظر آماری معنی‌دار بود. به‌طوری‌که، بیشترین عملکرد دانه (۱۶۰۱/۴ کیلوگرم در هکتار)، عملکرد زیست‌توده (۳۹۰۱ کیلوگرم در هکتار) و عملکرد اسانس (۳/۳۵ کیلوگرم در هکتار) در مالچ کلش گندم تحت شرایط کنترل کامل علف‌های هرز مشاهده شد. تراکم‌های ۶۶ و ۱۰۰ درصد شبدر، باعث خفگی و از بین رفتن کامل بوته‌های گشنیز شد. لذا، عملکرد دانه و زیست‌توده گشنیز در این تیمارها معادل صفر بود. همچنین، تراکم‌های پایین یونجه، تأثیر معنی‌داری بر کنترل علف‌های هرز نداشت. کنترل کامل علف‌های هرز باعث افزایش معنی‌داری در تمامی صفات ارزیابی شده در گشنیز شد. نتایج پژوهش حاضر نشان داد که استفاده از مالچ کلش گندم راه حل مناسبی برای کنترل علف‌های هرز گشنیز است که نه تنها در رشد و نمو گشنیز تداخلی ایجاد نمی‌کند، بلکه باعث کنترل مؤثر علف‌های هرز آن نیز می‌شود. از این رو با توجه به اهمیت کنترل تلفیقی علف‌های هرز در سیستم‌های کشاورزی پایدار، استفاده از مالچ کلش گندم را می‌توان به‌عنوان یکی از راهکارهای کاهش استفاده از سموم شیمیایی و کاهش آلودگی محیط زیست معرفی نمود.