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Use of Living, Mowed, and Soil-Incorporated Cover Crops for Weed Control in Apricot Orchards

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Received: 30 June 2018; Accepted: 13 August 2018; Published: 16 August 2018



Abstract: Apricot fruits provide important health, economic, and nutritional benefits. Weeds damage apricot production directly and host the pests that cause damages to apricot trees. However, very few studies are available on weed control in apricot orchards. This research work was aimed at evaluating five cover crops for weed suppression in apricot orchard. The effect of living, mowed, and soil-incorporated cover crops on weeds was recorded and compared with glyphosate application and mechanical weed control. The cover crops were *Vicia villosa* Roth., *Vicia pannonica* Crantz, *Triticale* + *V. pannonica*, *Phacelia tanacetifolia* Benth., and *Fagopyrum esculentum* Moench. Five major weed species in the experimental area were *Amaranthus retroflexus* L., *Convolvulus arvensis* L., *Tribulus terrestris* L., *Sisymbrium officinale* (L.) Scop., and *Sorghum halepense* (L.) Per. The highest biomass production was noted for *Triticale* + *V. pannonica* in 2015 and for *P. tanacetifolia* in 2016. Living cover crops were effective in decreasing the weed biomass compared with the control. Both mowing and soil incorporation of cover crops were effective in decreasing weed richness and density over control. Mowed or soil-incorporated cover crops were more effective than herbicide or mechanical weed control, while *F. esculentum* was the least effective cover crop for suppressing weeds in apricot orchard. The results of our studies implied that cover crops could be used for weed control in apricot, and their mowing or soil incorporation could enhance their efficacy.

Keywords: weeds; apricot; cover crops; non-chemical weed control; mowing; soil incorporation

1. Introduction

Apricot (*Prunus armeniaca* L.) is a member of family Rosaceae and genus *Prunus* and probably originated in the Central Asia, Turkey, or Western China. Fruit from apricot plants possesses high nutritional and health benefits and provides significant economic gains. Currently, the global production of apricots is 3.88 million tons, which is harvested from an area of 0.58 million ha [1]. Out of this apricot fruit production, 55.5% is contributed by Asia, nearly 26% and 14% is contributed by Europe and Africa, respectively while rest comes from other parts of the world. Turkey makes itself the largest producer of apricot with an average annual production of more than half million tons followed by Iran, Uzbekistan, Italy and Pakistan [1]. Climatic conditions in some areas of Turkey (particularly those in Malatya region) are highly supportive for apricot production, and the country is rich in genetic resources for the (apricot) fruit plants.

Apricot production is constrained by several factors including those of diseases, weeds, insect pests, soil erosion, and other biotic and abiotic factors. Weeds infest the apricot orchards and decrease its productivity and quality [2,3]. A study indicated that more than 50 weed species infested the apricot orchard, and important among these were *Euclidium syriacum* (L.) R. Br., *Veronica polita* Fr., and *Polygonum aviculare* L. [4]. Along with other damages, the weeds may also host the pathogens that cause diseases in apricot or other fruit plants. For instance, some of apricot weeds could act as a host for plum pox virus [5,6].

Herbicides may play a significant role for weed management in apricot plants. Glyphosate application and mechanical weed control are important among the current weed control practices in apricot farming. These two practices are expected to provide weed-free apricot fields. However, coverless (bare) apricot fields may result in increased erosion and run-off, decreased soil organic matter and moisture contents, and damage the soil physical and chemical properties [7]. Additionally, a few other problems are also associated with the use (particularly if over-applied) of herbicides for weed control in apricot fields. Evolution of herbicide resistance in weeds and environmental pollution are the most important among these [8–10].

The situation requires that there be weed control techniques that can provide weed suppression and soil cover as well. The use of cover crops may be the most suitable choice to achieve the objectives of soil conservation and weed management simultaneously. Previously, cover crops have been used for suppressing weeds in field crops and fruit orchards [11–14]. For example, cereal rye (*Secale cereale* L.) applied as cover crop could suppress the herbicide-resistant *Amaranthus palmeri* (S.) Wats. [15]. The use of cover crops has also been reported for suppressing weeds in perennial fruit orchards and other horticultural crops [16–19]. For example, cover crops of crimson clover (*Trifolium incarnatum* L.) and barley (*Hordeum vulgare* L.) reduced the weed infestation in vegetables such as crookneck squash (*Cucurbita pepo* L.) and broccoli (*Brassica oleracea* L.) by 50% compared to the un-weeded control [20]. Cover crops including *V. villosa* and *Festuca arundinacea* Schreb. were effective in suppressing the weeds and increasing yield of hazelnut orchards [21]. In addition to weed control, the cover crops could also improve soil chemical and physical properties [22].

Previously, very few studies have addressed weed infestations and their management in apricot cultivation. To the best of our knowledge, no studies were available that may explain the use of cover crops for weed control in apricot cultivation. Hence, the current research work was planned to assess the efficacy of several cover crops for weed control in apricot cultivation. We aimed to determine the weed suppression capacity of cover crops in living, mowed or soil incorporated forms. The study was also aimed at comparing the cover crops with mechanical control and nonselective herbicide (glyphosate) for a sustainable weed control in apricot orchards.

2. Materials and Methods

2.1. Experimental Site

Field studies were conducted during 2014 to 2016 in the experimental apricot orchard at İnönü University, Agricultural Faculty, Turkey on a clay soil (20% sand, 28% silt, 52% clay, 1.7% organic matter, and pH 7.4). The experimental site was located at 38.47 N–38.34 E and had an average temperature of 13.4 °C in 2015–2016 growing season and mean annual precipitation of 420 mm. The apricot orchard was 10 years old. Plant spacing was 8 m within the row and 8 m between the rows.

2.2. Field Trial

Annual cover crops were used for weed control in the experimental area in the apricot orchards. *Vicia villosa* (hairy vetch), *V. pannonica* (Hungarian vetch), a mixture of *V. pannonica* Crantz and *Triticale* (*V. pannonica* 70% + *Triticale* 30%), and *Phacelia tanacetifolia* (lacy phacelia) were used as winter cover crops, and *Fagopyrum esculentum* (buckwheat) was used as summer cover crop. *Fagopyrum esculentum*, which is a concealment plant for the summer, was planted on 21 April 2014 and 5 May 2015, and the

other winter covering plants were planted in the fall periods of the years on 23 October 2014 and 23 October 2015. Before planting of the cover crops, weeds present in the field were removed either manually or mechanically. In each of the study years, the first soil cultivation was done during the first week of November, and soil preparation was done in mid-April before sowing of the cover crops (for the summer cover crops). For the winter cover crops, the first soil cultivation was done in mid-September, and soil preparation was done during the first week of November. There was a 50 cm distance between the cover crops and the apricot plants. The results of the experiments were recorded in 2015 and 2016 for summer and winter cover plants.

The experiments were established in a randomized block design with four replications. Experiment also included control plots, herbicide applications and mechanical weed control. Each plot was 80 m² (4 × 20 m). Consecutive plots were separated with a buffer zone with no cover crop. The cover crop seeds were broadcast and incorporated into the soil. Seeding rates were 150 kg ha⁻¹ for hairy vetch and Hungarian vetch, 30 kg ha⁻¹ for lacy phacelia and 50 kg ha⁻¹ buckwheat. The cover crop treatments were maintained in the same (respective) plots throughout the duration of the experiment. Cover crops were at flowering stage on 15 May 2015 in the first year of study and on 24 May 2016 in the second year of study. After the flowering period of the cover crops, half of the parcels with cover crops in experiment were incorporated into the soil using two passes of a double disk cultivator to a depth of approximately 10 cm (i.e., soil incorporation treatment), and the other half was mowed without any treatment and left as mulch on the soil (i.e., mowing treatment). Cover crops were mowed or incorporated into the soil on 20 May during 2015 and 3 June during 2016. Mechanical weed control comprised use of rotary hoeing and herbicide treatments included the application of glyphosate at 2.40 kg a.i. ha⁻¹ after the weeds emerged and were growing actively. Herbicide application and mechanical weed control were practiced when the weeds were at 4–8 leaves stage (20 May 2015, and 25 May 2016). Glyphosate (isopropylamine salt, 360 g a.i. L⁻¹) was applied at 2880 mL ha⁻¹ (1.39 kg a.i. ha⁻¹). Herbicide was applied with a spraying volume of 250 L ha⁻¹ at 303.97 kPa pressure with a field sprayer, pressurized by a pump, and pulled by a tractor. The sprayer was fitted with flat fan nozzles and had a 12 m working width. Tractor speed during spray was 6 km/h.

Prior to treatments (mowing or soil incorporation) of the cover crops, aboveground biomass samples of the cover crops were collected in a randomly selected 50 × 50 cm quadrat in each plot. At the same time, weed biomass was measured by cutting all weeds at ground level in a 50 × 50 cm quadrat placed in each plot. Weeds and cover crops were dried at 105 °C for 24 h to obtain dry biomass. To determine the suppressive effects of cover crops, weed species richness and weed density were assessed at 7, 14, and 28 days after treatments (mowing, soil incorporation, herbicide application, or mechanical weed control) from all plots using a 50 × 50 cm quadrat placed randomly in the plots.

2.3. Statistical Analyses

Data from each year were analyzed separately because of significant year-by-treatment effects except for the data on weed species richness and weed density. Data were subjected to ANOVA and treatment means were compared using Duncan's protected LSD tests at the 0.05 probability level. Species richness was calculated using the number of weed species recorded in each plot. Data were transformed as needed before analysis using either arcsine square root or log transformations. Untransformed means were presented in the text for clarity of presentation.

3. Results

Dominant weed species in the experimental area in apricot orchard included *A. retroflexus*, *C. arvensis*, *T. terrestris*, *Sisymbrium officinale*, *Sorghum halepense*, *Lamium amplexicaule* L., *Chenopodium album* L., *Thlaspi arvense* L., and *Vaccaria pyramidata* MEDIK (Table 1). Densities of other weed species such as *Lactuca serriola* L., *Sinapis arvensis* L., and *Glycyrrhiza glabra* Linn. were lower than 1%. Weed counts and weed weights taken in both years showed that *A. retroflexus* (22%), *C. arvensis* (16%),

T. terrestris (16%), *S. officinalis* (14%), and *S. halepense* (7%) contributed over 75% of the total weed populations (Table 1).

Table 1. Major weed species present in the experimental area and their relative proportion just before treatments (combined means of 2015 and 2016).

Weed Species	Bayer Code	Relative Proportion (%)
<i>Amaranthus retroflexus</i> L.	AMATR	22
<i>Convolvulus arvensis</i> L.	CONAR	16
<i>Tribulus terrestris</i> L.	TRBTE	16
<i>Sisymbrium officinale</i> (L.) Scop.	SSYOF	14
<i>Sorghum halepense</i> (L.) Per.	SORHA	7
<i>Lamium amplexicaule</i> L.	LAMAM	3
<i>Chenopodium album</i> L.	CHEAL	3
<i>Thlaspi arvense</i> L.	THLAR	3
<i>Vaccaria pyramidata</i> Medik.	VAAPY	3
<i>Papaver rhoeas</i> L.	PAPRH	2
<i>Cirsium arvense</i> (L.) Scop.	CIRAR	2
<i>Xanthium strumarium</i> L.	XANST	1
<i>Portulaca oleracea</i> L.	POROL	1
<i>Convolvulus galaticus</i> Rost. ex Choisy	CONGA	1
<i>Anthemis arvensis</i> L.	ANTAR	1
Others		<5

Cover crop emergence was similar in 2015 and 2016 growing seasons (data not shown). However, significantly higher biomass was produced in 2016 than in 2015 (Figure 1). *Triticale* + *V. pannonica* produced significantly higher biomass ($6212.5 \text{ kg ha}^{-1}$) than all other species in 2015. *P. tanacetifolia* produced higher biomass (6511 kg ha^{-1}) in 2016. The lowest cover crop dry biomass was obtained from *V. villosa* (2575 kg ha^{-1}) in 2015 and *F. esculentum* (3440 kg ha^{-1}) in 2016. Statistical difference for the quantities of dry biomass production by cover crops was insignificant in 2016. The greater biomass production in the second year could be attributed to more optimal conditions for growth of the cover crops.

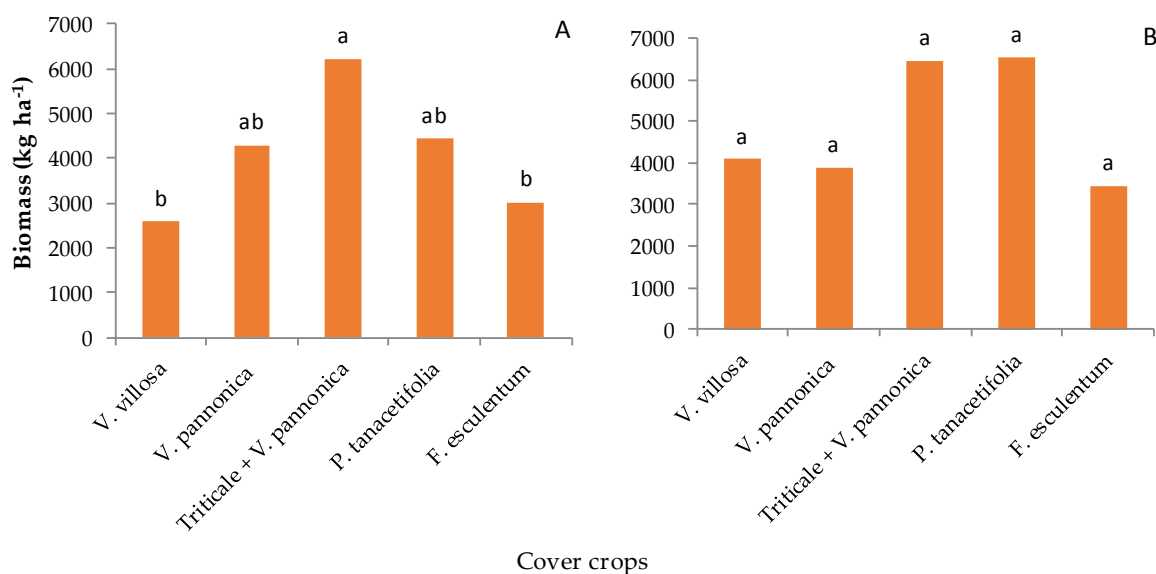


Figure 1. Biomass production (kg ha^{-1}) of cover crops during the year (A) 2015 and (B) 2016. The columns not sharing a letter in common differ significantly at $p < 0.05$.

The effects of the cover crops on weed dry biomass production just before treatment (mowing or soil incorporation of cover crops) were consistent in each year (Figure 2). In 2015, weed biomass was the highest in the control i.e., without cover crops followed by *V. pannonica*, *Triticale + V. pannonica*, *V. villosa*, *F. esculentum*, *P. tanacetifolia*, mechanical weed control, and herbicide applications. In 2016, the weed biomass was highest in mechanical control and non-treated parcels followed by *V. pannonica*. Other treatments (*V. villosa*, *Triticale + V. pannonica*, *F. esculentum*, *P. tanacetifolia*, and glyphosate) had the lowest and statistically equal weed dry biomass. *P. tanacetifolia* was the most suppressive species, reducing total weed dry biomass by 83.64% in 2015 and by 53.7% in 2016.

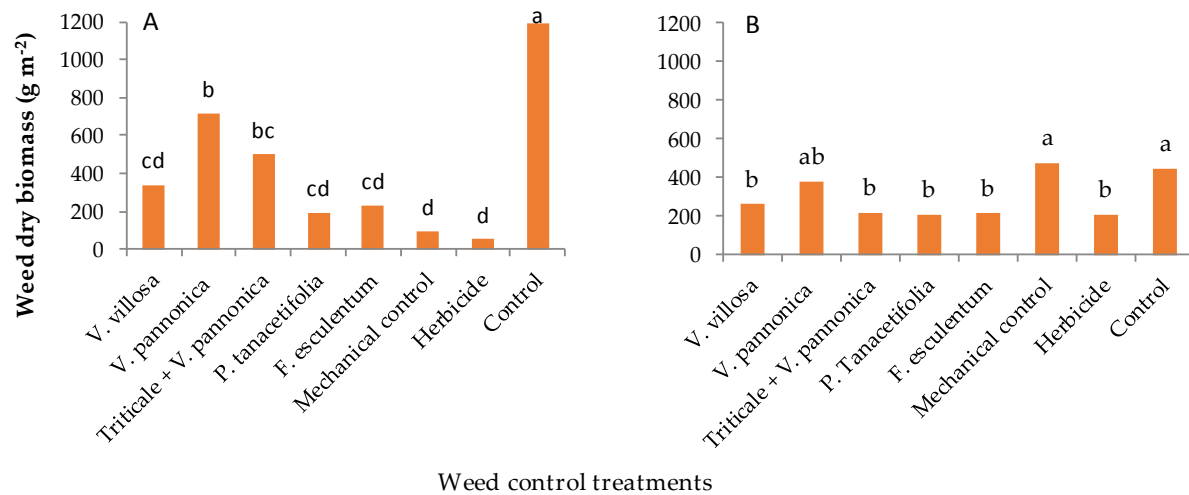


Figure 2. Effects of various living cover crops on the dry biomass production (g m⁻²) of weed species during (A) 2015 and (B) 2016. The columns not sharing a letter in common differ significantly at $p < 0.05$.

In addition to weed dry biomass reduction by living cover crops, mowed and soil incorporated cover crops also caused a decrease in weed species richness (Figures 3 and 4). Data indicated that mowed cover crops including *V. villosa*, *V. pannonica*, *Triticale + V. pannonica*, and *P. tanacetifolia* caused a significantly higher decrease in weed species richness (number) than untreated control, glyphosate application, mechanical weed control, and a cover crop *F. esculentum* (Figure 3). The effect of cover crops was sustainable even after one month of mowing (the date for last data recording).

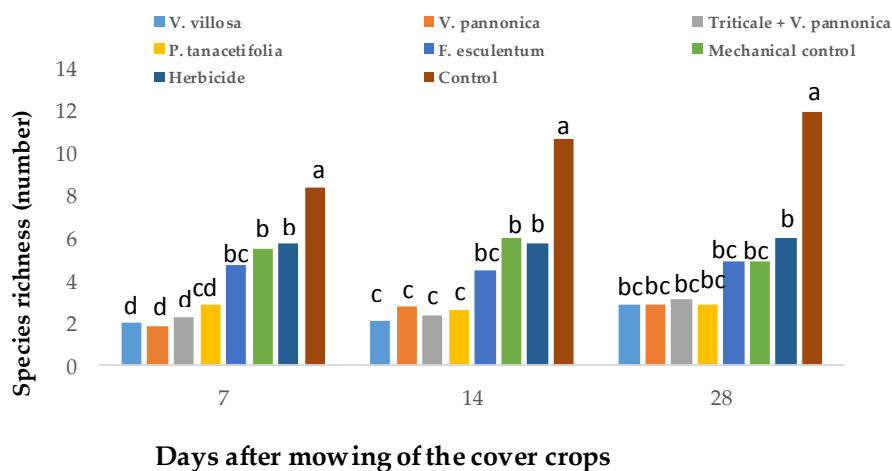


Figure 3. Effect of mowed cover crops, mechanical control, and herbicide application on weed richness (number of species) in apricot orchard. For each data recording (7, 14, or 28 days), the columns not sharing a letter in common differ significantly at $p < 0.05$. Data is an average of two years.

Soil incorporation of cover crops had results similar to mowing on weed suppression in apricot orchards (Figure 4). Mechanical weed control or glyphosate application had a lower effectiveness against species richness than the soil incorporated cover crops i.e., *P. tanacetifolia*, *V. villosa*, *V. pannonica*, and *Triticale* + *V. pannonica*. *F. esculentum* was least effective among the cover crops.

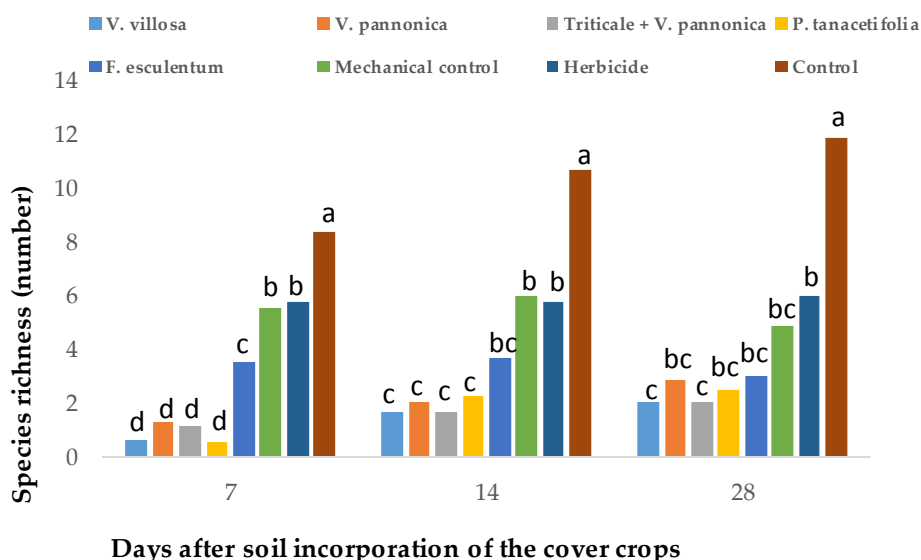


Figure 4. Effect of soil incorporated cover crops, mechanical control, and herbicide application on weed richness (number of species) in apricot orchard. For each data recording (7, 14, or 28 days), the column not sharing a letter in common differ significantly at $p < 0.05$. Data is an average of two years.

Both the cover mowing and soil incorporation had significantly decreased the weed density in apricot orchard (Figures 5 and 6). Among the cover crops, *F. esculentum* (either mowed or soil incorporated) had the lowest effectiveness to decrease weed density in apricot. Mechanical weed control had a weed density close to control (weedy) treatment followed by glyphosate application. The most effective cover crops (both for mowing and soil incorporation) for decreasing weed density in apricot were *V. villosa*, *V. pannonica*, *P. tanacetifolia*, and *Triticale* + *V. pannonica* (Figures 5 and 6).

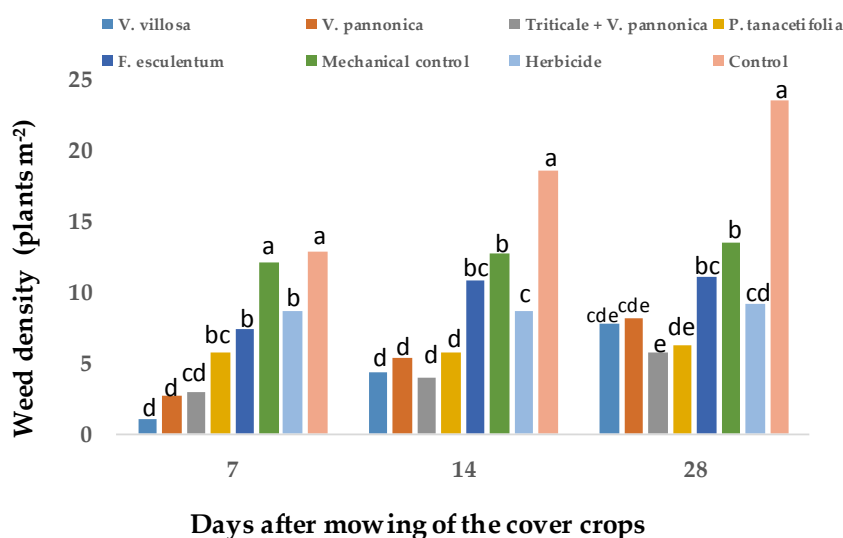


Figure 5. Effect of mowing of cover crops, mechanical control, and herbicide application on weed density in apricot orchard. For each data recording (7, 14, or 28 days), the columns not sharing a letter in common differ significantly at $p < 0.05$. Data is an average of two years.

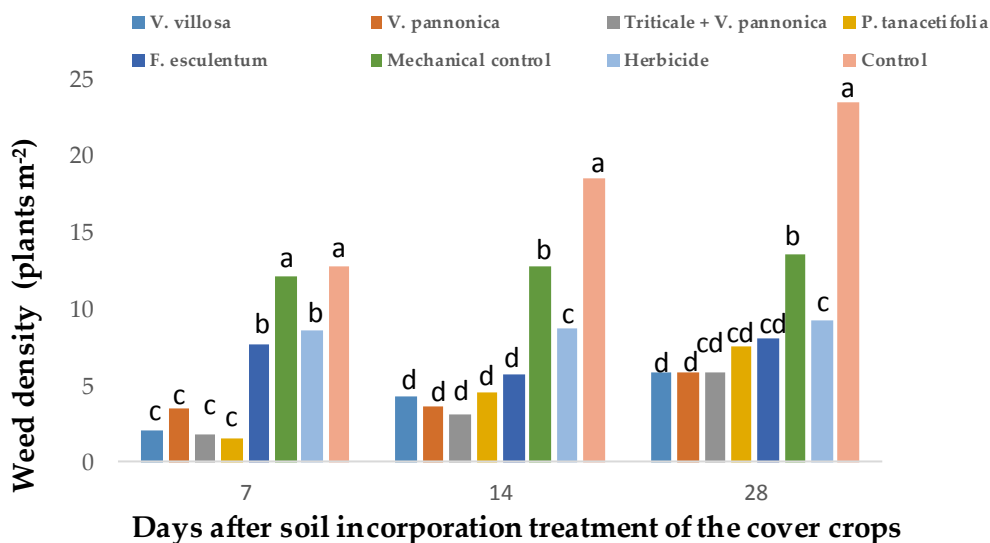


Figure 6. Effect of soil incorporation of cover crops, mechanical control, and herbicide application on weed density in apricot orchard. For each data recording (7, 14, or 28 days), the columns not sharing a letter in common differ significantly at $p < 0.05$. Data is an average of two years.

4. Discussion

The results of this research work highlighted that cover crops can be effective in reducing the weed density, dry weight, and infestation in apricot orchards. Cover crop plants reduce the development of weeds and seed production by directly competing with weeds for light and nutrients [23–25]. The role of cover crop plants in decreasing weed density and biomass is due to their physical effects, reduction of light permeability, changes in soil temperature, increase in soil moisture, and allelochemical interactions [12,26–29]. The suppressive effects of hairy vetch on weeds have been well-reported previously, and this could suppress the weeds by more than 60% [30,31]. This cover crop (hairy vetch) was also effective in suppressing weeds in organically grown lettuce and pepper [32,33]. Cover crops' biomasses were reasonably good to suppress the weeds. Higher cover crop biomass was obtained in the second year of study than the first year. Particularly, during the spring season of the first year of study, there were high rains that supposedly influenced the weeds positively and the cover crops negatively.

In our findings, lacy phacelia was the most effective cover crop that suppressed the weeds by almost 75%, followed by buckwheat that registered a 73% weed suppression, and hairy vetch with a 63% suppression of weeds. The lowest weed suppression was obtained from the Hungarian vetch cover crop plants (33%), whereas this effect was over 50% in Hungarian vetch + *Triticale* mixture. These results are supported by previously reported research work. Previously, lacy phacelia cover crop was reported to suppress *Echinochloa crus-galli* (L.) P.Beauv., *C. album*, and *Portulaca oleracea* L. in maize plantings [34].

Efficacy of cover crops against weeds has been reported in the previous literature. For example, *Melilotus officinalis* (L.) Pall. as a cover crop in the fallow systems could reduce weed biomass over 95% and could also suppress the weeds when residues of this cover crop were mixed in the soil [35]. Although, this much high weed suppression was not obtained in our research, we can safely recommend that cover crop can suppress weeds, particularly in the fruit gardens. Legume cover crops could also add nutrients to soil along with suppressing weeds, and this may play an important role in conserving the soil and sustaining the agricultural production [36]. We supposed that weed suppression obtained in our studies was a result of both a physical and chemical interference of cover crops with weeds. Recent literature establishes that cover crops suppress weeds both by their physical pressure and chemical interactions [11,12,29,37].

Allelopathic potential is one of the factors that help the cover crops to suppress weeds [12,26,38]. Previous literature reports the allelopathic potential of cover crops that have been found effective against weeds [39–42]. For example, Sturm et al. [39] reported that buckwheat caused an allelopathic suppression of *Stellaria media* (L.) Vill., while palmitic acid gallic acid were described as potent allelochemicals of buckwheat [43]. Allelopathic potential of hairy vetch has also been reported by several researchers [40,41]. Cyanamide was reported as an allelochemical from hairy vetch, which could inhibit the growth of other plants [41,42].

The treatments were maintained in the same fields in the first and the second year of study. Hence, this may have provided time and opportunity to the perennial weeds to get established in the fields, and ultimately the efficacy of mechanical weed control was decreased in the second year of the study. It was observed that perennial weeds such as *S. halepense* and *Cirsium arvense* (L.) Scop. had high infestation in the mechanical weed control parcels.

The results of this study are important in the wake of problems associated with application of herbicides (such as herbicide resistance evolution in weeds or environmental pollution) and provide an alternative for sustainably controlling weeds in apricot orchards [27,28]. Cover crops tested in this work were generally effective in suppressing weeds in either living, mowed, or soil-incorporated forms. The living form of cover crops had an efficacy lower than glyphosate or mechanical weed control (Figure 2). However, these were more effective than glyphosate or mechanical control after mowing or soil incorporation (Figures 3–6). From this, we can safely suggest mowing or soil incorporation of living cover crops for increasing their weed suppression efficacy. Nevertheless, along with weed control, the cover crops also play a role in sustaining soil resources (reducing soil erosion, improving soil moisture and organic matter status, etc.) [7]. The results also provide an opportunity for effective non-chemical weed control, and this in turn is important for organic fruit production.

5. Conclusions

The results of this study are important in the perspective of organic fruit production. The most important weeds in the experimental area were *A. retroflexus*, *C. arvensis*, *T. terrestris*, *S. officinale*, and *S. halepense*. Non-chemical methods such as cover crops could effectively control weeds in the apricot orchard. Among the weed control treatments, the highest weed suppression was obtained with the cover crops including lacy phacelia, buckwheat, hairy vetch and *Triticale* + Hungarian vetch. Mowing or soil-incorporation of the cover crops were also helpful in suppressing the weeds, and could provide weed control better than the glyphosate application or mechanical weed control.

Author Contributions: Conceptualization, Funding Acquisition, and Methodology: N.T., D.I., and Z.D.; Statistical analysis and Writing: N.T. and K.J.

Funding: This research was funded by the Scientific and Technological Research Council of Turkey grant number (Project No. 213 O 109).

Acknowledgments: The authors thank the Scientific and Technological Research Council of Turkey (TUBİTAK) for the financial support for this project (Project No. 213 O 109).

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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