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Effects of Cover Crops on Yield and Quality of Kiwifruit

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Additional index words: Competition, fruit quality, kiwifruit, live mulch.

Abstract

This study was carried out to investigate the effects of some cover crops used in kiwi orchards for weed control on fruit yield and quality. Experiments were conducted in Samsun province of Turkey between the years 2012 - 2014 in a randomized complete block design with four replications. Nine experimental treatments were arranged as single *Trifolium repens* L. (Tr), *Festuca rubra rubra* L. (Frr), *F arundinacea* (Fa); a mixture of these three species (40, 30 and 30%), *Vicia villosa* Roth. and *Trifolium meneghinianum* Celm sown plots, weedy control plot, mechanical control plot and herbicide-treated plot. Cover crop treatments had significant effects on yield and quality traits of kiwi fruit. The highest yield was obtained with *T. meneghinianum* (17,879 kg·ha^{-1}), and the lowest yield was obtained with mechanical control (8,304 kg·ha^{-1}). The highest values for fruit length were obtained with *V. villosa* (74.9 mm) and *F. arundinaceae* (72.9 mm), whereas the lowest fruit length was obtained with mechanical control (62.4 mm). The highest values of fruit width were obtained for *F. arundinaceae, F. rubra rubra, T. Meneghinianum*, and *V. villosa* with 57.2 mm, 56.7 mm, 56.7 mm and 56.6 mm of fruit width, respectively. The lowest values of fruit width were mechanical control (53.2 mm), herbicide control (54.1 mm), and Tr+Frr+Fa mixture (54.2 mm). For the shape index, the highest values of 0.89 and 0.87 were associated with *T. meneghinianum* and mechanical control, respectively, and the lowest value of 0.76 was obtained with the *V. villosa*. The highest values for fruit weight were obtained from the *V. villosa* at 142.1 g and weedy control at 135.8 g. The lowest fruit weight of 74.1 g was obtained from mechanical control. Total soluble solids concentration (TSS) was highest for weedy control with a value of 9.4%, whereas lowest TSS were obtained with Tr+Frr+Fa mixture with a value of 7.8%.

Present results revealed that cover crops could be used as an alternative and efficient tool for weed control in kiwi orchards. Further research and grower training are recommended for the widespread use of cover crops in kiwi orchards.

Kiwifruit has a high economic value; thus, kiwi farming is continuously increasing both in Turkey and in the world (Canan et al., 2018). Kiwifruit (*Actinidia deliciosa* A. Chev.) is native to China, but production was initiated in New Zealand at the beginning of the 1900s and in Europe at the beginning of the 1960s (Atak et al., 2015; Guroo et al., 2017). In Turkey, kiwi was first grown at the Atatürk Horticultural Central Research Institute in 1988 (Sezer and Kolören, 2019). These early trials revealed that kiwifruit could be produced in coastal sections of the Black Sea and Marmara regions (Öztürk et al., 2012; Atak, 2015). Later, kiwifruit production sites and quantities rapidly increased in Turkey (Sezer and Kolören, 2019).

World annual kiwifruit production was 4,022,665 t in 2018, and China, Italy, New Zealand, Iran, Chile, and Turkey are the leading producers (http://www.fao.org/faostat/en/#data/QC/visualize). Turkey, with 63,798 tons of production from 3,066 ha, is sixth in world kiwifruit production (www.tuik.gov.tr).

There are various biotic and abiotic factors limiting kiwifruit production and yield and weeds are among the most significant factors. Total herbicides and mechanical control are

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practiced for weed control in kiwi orchards of Turkey. However, herbicides have various side-effects and mechanical control practices may damage plants. Such practices are also costly and influence organic matter content of surface soils. Therefore, there is a continuous search for alternative weed control methods. Cover crops may offer an alternative for weed control in kiwi orchards.

Kiwifruit production is becoming more popular along the coastal zones of Turkey. It was initiated as an alternative product, especially in the Black Sea Region, then increasing demands have made kiwifruit an alternative source of income for local farmers.

Besides total herbicides, soil tillage is also commonly used as a mechanical control practice in fruit culture. Roots extent to the edge of the canopy and of fruit trees. Soil tillage may damage capillary roots close to the soil surface and suppress nutrient uptake of the trees and may make trees prone to pests and diseases. Therefore, unless necessary, soil tillage is rarely recommended in modern farming systems. Ideally, alternative measures that provide weed control without disrupting the balance of agroecosystems and improve biodiversity are sought for use in orchards of Turkey. Cover crops are considered among the most preferable practices (Kitiş, 2010; Tursun et al., 2018).

In recent years, especially in European orchards, cover crop treatments suppressed the growth and development of weeds through mechanical blockage, allelopathy and natural competition (Işık et al., 2009, 2013, 2014). Cover crops improved soil structure and regulated soil-water balance, increased carbon dynamics, organic matter content and microbial functions, had significant contributions to soil fertility (Robacer et al., 2016; Demir et al., 2019; Demir and Işık, 2019) and prevented soil erosion (Işık et al., 2009, 2014). Leguminous cover crops fix atmospheric nitrogen and serve as insectarium for various beneficial insects and enriched macrofauna as it was for earthworms (Demir et al., 2019; Demir and Işık, 2019). On the other hand, soil surfaces become barren with herbicide treatments in the Black Sea region of Turkey with quite high precipitation levels; then, the soil surface is prone to water and wind erosion. Cover crops may also influence fruit yield and fruit quality based on crop species and regional climate conditions (Alvarez et al., 2017; Işık et al., 2018). Hoagland et al. (2008) used cover crops of *Trifolium subterraneum*, *Medicago lupulina*, and *M. polymorpha* as live mulch in newly established apple orchards. They indicated that cover crop treatments provided higher nitrate concentrations to the soil, enhanced soil microbial activity, and improved tree growth and development. Mullinix and Granatstein (2011) used *Trifolium repens* as a cover crop in a mature apple orchard in Washington and reported that cover crop treatments improved tree growth and yields and provided perfect weed control. This study was conducted to investigate the effects of cover crop and the other weed control treatments on kiwifruit yield and quality. With this study, cover crop treatments were examined for the first time for ground management in kiwi orchards of Turkey.

Materials and Methods

This study was conducted at the Black Sea Agricultural Research Institute (36’40” N latitude; 41’13” E longitude; 17 m altitude) in the Samsun province in the Black Sea region of Turkey between 2012-2014. The experimental kiwi orchard was 12 years old and established with Hayward (*Actinidia deliciosa*) cultivar.

Soil physical and chemical characteristics of the experimental site are provided in Table 1. Experimental soils were loamy in texture, non-saline with slight alkaline pH, and moderate organic matter content (Table 1). The experimental site has a mild climate with an annual average temperature of 14.5 °C and total precipitation of 717.1 mm (Fig.1). All plants were fertilized according to soil

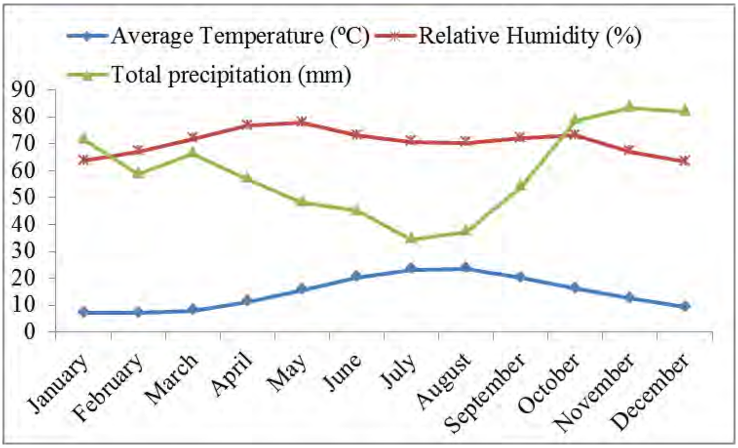

Fig. 1. Average temperature, relative humidity and precipitation months in long-term (1929-2018).

analysis and irrigated with drip irrigation when soil moisture is reduced by 40%.

The experiment was conducted in randomized block design with four replications of 9 treatments. Each plot (7 × 5 m) was composed of two kiwi trees which were located in the middle of the plot. Experimental treatments were arranged as single *T. repens*, *F. rubra rubra*, *F. arundinacea* treatments, a mixture of these three species (40, 30 and 30%), *V. villosa*, and *T. meneghinianum* sown plots, weedy control plot, mechanical control plot, and a herbicide-treated plot. Consecutive plots were separated with a buffer zone with no cover crop. Before planting of the cover crops, weeds present in the field were removed either manually or mechanically. First soil cultivation was done during the first week of Nov., and in early April soil was prepared before sowing of the cover crops. Weeds were controlled mechanically twice a year with a disk harrow set at 8-10 cm deep. Glyphosate isopropylamine salt (360 g a.i · L^{-1}) was applied at the rate of 6000 ml·ha^{-1} with a knapsack sprayer (Honda WJR 2225) at 3 atm pressure (303.97 kPa) and 250 L·ha^{-1}. Herbicide and mechanical weed control were applied when the broad-leaf species had 4-8 leaves, and narrow-leaf species were 10-15 cm in height.

Cover crops were sown at the beginning of April 2012. *T. repens* was sown at the rate of 50 kg·ha^{-1}, *F. rubra rubra*, and *F. arundinacea* at 80 kg ha^{-1}, *V. Villosa* at 150 kg ha^{-1} and *T. meneghinianum* at 50 kg ha^{-1} (Anonymous, 2009). Growth and development of cover crops were visually monitored periodically. Perennial cover crops were mowed two times

Table 1. Soil physical and chemical characteristics of the experimental site.[z]

Sand (%)	Silt (%)	Clay (%)	Total Salt (%)	pH
44.35	32.62	23.03	0.52	7.55
Ca me 100 g^{-1}	Mg me 100 g^{-1}	Na me 100 g^{-1}	K me 100 g^{-1}	Organic matter (%)
19.33	4.45	043	0.87	1.53

[z] Soil, plant and water analysis laboratory of Black Sea Agricultural Research Institute.

Table 2. Effects of cover crops on kiwi fruit length, width, shape index (width:length ratio) over three years.

Treatments	Length (mm)				Width (mm)				Shape index			
	2012	2013	2014	Mean	2012	2013	2014	Mean	2012	2013	2014	Mean
T. repens	69.9 bc[y]	71.0 abc	59.9 c	66.9 c	58.9 ab	62.4 a	43.2 e	54.8 bc	0.84 ab	0.88 a	0.75 cd	0.82 b
F. rubra rubra	69.2 bc	70.4 abc	71.7 b	70.5 b	59.9 a	59.4 bc	50.9 bc	56.7 a	0.87 a	0.84 abcd	0.72 d	0.81 bc
F. arundinacea	71.2 ab	73.1 a	74.4 b	72.9 a	59.1 ab	60.0 abc	52.7 ab	57.2 a	0.83 bc	0.82 cd	0.71 d	0.78 bcd
Tr+Frr+Fa mixture[z]	70.1 abc	71.2 abc	68.8 b	70.1 b	55.6 d	57.5 bcd	49.5 cd	54.2 c	0.79 d	0.80 d	0.73 cd	0.78 cd
V. villosa	71.2 ab	72.7 a	80.7 a	74.9 a	56.7 bcd	60.4 ab	52.7 abc	56.6 a	0.80 cd	0.83 bcd	0.65 d	0.76 d
T. meneghinianum	71.7 a	72.1 ab	56.9 cd	66.9 c	56.4 cd	58.5 bcd	55.2 a	56.7 a	0.79 d	0.81 cd	1.08 a	0.89 a
Herbicide control	69.9 abc	69.5 bcd	61.5 c	67.0 c	56.3 cd	56.3 d	49.9 bc	54.1 c	0.81 cd	0.81 cd	0.83 bc	0.81 bc
Mechanical control	66.5 d	66.8 d	53.7 d	62.4 d	56.5 cd	57.1 cd	46.1 de	53.2 c	0.85 ab	0.85 abc	0.9 b	0.87 a
Weedy control	68.5 cd	68.5 cd	70.4 b	69.1 bc	58.1 abc	59.7 abc	51.4 bc	56.4 ab	0.85 ab	0.87 ab	0.74 cd	0.82 b

[z] Cover crops mixture of *T. repens* (40%), Frr: *F. rubra rubra* (30%), Fa: *F. arundinacea* (30%),
[y] Means within columns followed by common letters do not differ at the significantly at the 5% level, by LSD.

(beginning of June and Aug.) each year during the study. Trees in each plot were harvested at harvest maturity to investigate the effects of cover crops on fruit yield. Harvested fruits were weighed, then converted into yield per hectare. Pomological measurements (fruit width, fruit length, shape index (width:length ratio), fruit weight, and total soluble solid concentration) were also performed on ten fruits randomly selected from each plot by the methods specified in Göral (1986) and Uzun and Basım (2003). Fruit thinning was performed to adjust the crop loads on all plants to similar levels.

Data homogeneity was checked with Levene' test. Experimental data were then subjected to one-way analysis of variance (ANOVA) for each year and combined years. Means were compared with the Least Significant Difference (LSD) test at P<0.05 significance level. Data were analyzed with SAS's Proc Mixed (SAS 9.1 version, USA).

Results

Effects of cover crops on fruit lengths. The effects of cover crops on fruit lengths were significant each year and when averaged over years (P<0.01). Averaged over three years, the greatest fruit length (74.90 mm) was from *V. villosa* plots, and *V. villosa* was not significantly different from *F. arundinacea* (72.9 mm); thus they were placed into the same group (Table 2). The lowest fruit length (62.4 mm) was obtained from mechanical control plots. When the years were evaluated separately, the greatest fruit length was obtained from *T. meneghinianum* plots in 2012 (71.7 mm), which was not different from *V. Villosa*, from *F. arundinacea* in 2013(73.1 mm) and *V. villosa* plots in 2013 (80.7 mm). The lowest fruit lengths were obtained from the mechanical control plots in all years, but mechanical control plots were not significantly different from weedy control plots in 2012 and 2013 (Table 2).

Effects of cover crops on fruit widths. The differences in fruit widths of the experimental treatments were significant (P<0.01) each year and combined over years (Table 2). Averaged over three years, the greatest fruit width was obtained from *F. arundinacea* plots (57.2 mm), but it was not significantly different from *F. rubra rubra* (56.7 mm), *V. villosa* (56.6 mm) and *T. meneghinianum* (56.7 mm). Thus, they were all placed into the same group. The lowest fruit width was obtained from mechanical control plots (53.2 mm), but it was not significantly different from herbicide-treated plots (54.1 mm) and perennial cover crop mixture plots (54.2 mm), thus they were placed into the same group. When the years were evaluated separately, the greatest fruit width was obtained from *F. rubra rubra* plots in 2012 (59.9 mm), from *T. repens* plots in 2013 (62.4 mm) and *T. meneghinianum* plots in 2014 (55.2 mm). The lowest fruit width was obtained from herbicide-treatment plots in 2012 and 2013 (56.3 mm) and from *T. repens* plots in 2014 (43.2 mm) (Table 2).

Effects of cover crop treatments on fruit shape index. The effects of the experimental treatments on fruit shape index was highly significant ($P<0.01$). Averaged over three years, the highest shape index was obtained from *T. meneghinianum* plots (0.89), and it was not significantly different from mechanical control plots (0.87). Thus, they were placed into the same group. The lowest shape index was obtained from *V. villosa* plots (0.76) (Table 2). When the years were evaluated separately, the highest fruit shape index was obtained from *F. rubra rubra* plots in 2012 (0.87), from *T. repens* plots in 2013 (0.88) and from *T. meneghinianum* plots in 2014 (1.08). The lowest shape index was obtained from *T. meneghinianum* and mixture plots (0.79) in 2012, from mixture plots in 2013 (0.80) and from *V. villosa* plots in 2014 (0.65) (Table 2).

Effects of cover crop treatments on fruit weight. Cover crop treatments significantly influenced fruit weights ($p<0.01$) (Table 3). Averaged over three years, the greatest fruit weight was obtained from *F. arundinacea* plots (121.6 g), but it was not significantly different from *V. villosa* plots (121.5 g). The lowest fruit weight was obtained from the mechanical control plots (91.3 g) (Table 3). When the years were evaluated separately, the greatest fruit weight was obtained from *F. arundinacea* plots in 2012 and 2013 (119.6 and 116.1 g) and from *V. villosa* plots in 2014 (142.1 g). The lowest fruit weight was obtained from mechanical control plots in 2012 and 2014 (97.9 and 74.1 g) and from weedy control plots in 2013 (97.4 g), but it was not significantly different from mechanical control plots (98.6 g).

Effects of cover crop treatment of total soluble solid concentrations (TSS). The effects of ground management practices on TSS of kiwifruit were significant over the years and combined years ($P<0.05$) (Table 3). Averaged over three 3 years, the highest TSS was obtained from weedy control plots (9.4%), but it was not significantly different from mechanical control and *T. repens* plots (9.1), *F. arundinacea* and *T. meneghinianum* plots (8.9%). The lowest TSS was obtained from mixture plots (7.8%) (Table 3). When the years were evaluated separately, the highest TSS was obtained from weedy control plots in 2012 and 2013 (10.3 and 10.1%) and

Table 3. Effects of cover crops on fruit weight and total soluble solids concentration (TSS) over three years.

Treatments	Fruit weight (g)				TSS content (%)			
	2012	2013	2014	Mean	2012	2013	2014	Mean
T. repens	111.9 ab[y]	106.0 bc	87.6 ef	102.5 d	8.5 bc	8.9 bc	10.3 a	9.1 ab
F. rubra rubra	113.8 ab	111.6 ab	117.9 bc	114.9 b	7.5 cd	8.5 bc	9.6 bc	8.3 cd
F. arundinacea	119.6 a	116.1 a	129.2 ab	121.6 a	9.1 b	9.2 ab	9.1 cd	8.9 ab
Tr+Frr+Fa mixture[z]	107.8 b	109.1 abc	111.9 cd	110.7 bc	7.2 d	8.2 c	8.7 de	7.8 d
V. villosa	112.0 ab	108.8 abc	142.1 a	121.5 a	8.1 bcd	8.5 bc	10.1 ab	8.7 bc
T. meneghinianum	111.5 ab	106.1 bc	120.1 bc	113.0 b	8.8 b	8.7 bc	9.8 ab	8.9 ab
Herbicide control	106.0 bc	104.2 cd	99.6 de	104.5 cd	8.7 bc	9.1 bc	8.9 de	8.7 bc
Mechanical control	97.9 c	98.6 d	74.1 f	91.3 e	9.1 b	9.4 ab	9.7 bc	9.1 ab
Weedy control	109.8 b	97.4 d	135.8 a	115.4 ab	10.3 a	10.1 a	8.4 e	9.4 a

[z] Cover crops mixture of *T. repens* (40%), Frr: *F. rubra rubra* (30%), Fa: *F. arundinacea* (30%),
[y] Means within columns followed by common letters do not differ at the significantly at the 5% level, by LSD.

from *T. repens* plots in 2014 (10.3%). The lowest TSS was obtained from mixture plots in 2012 and 2013 (7.2 and 8.2%) and from weedy control plots in 2014 (8.4%) (Table 3).

*Effects of cover crop treatments on yields***.** Ground management practices significantly influenced yield (kg·ha^{-1}) (Table 4). Averaged over three years, the greatest yield was obtained from *T. meneghinianum* plots (17879 kg ha^{-1}), but it was not significantly different from *F. rubra rubra* (17,358 kg·ha^{-1}) and mixture plots (16,857 kg·ha^{-1}). The lowest yield was obtained from mechanical control plots (8,304 kg·ha^{-1}), but it was not significantly different from weedy control plots. When the years were evaluated separately, the greatest yield was obtained from *F. rubra rubra* plots in 2012 (38,456 kg·ha^{-1}), *T. meneghinianum* plots in 2013 (21,406 kg·ha^{-1}) and *T. repens* plots in 2014 (6,064 kg·ha^{-1}). The lowest yield was obtained from weedy control plots in 2012 (16,223 kg·ha^{-1}), and mechanical control plots in 2013 and 2014 (5,938 and 1,302 kg·ha^{-1}) (Table 4). Yields were quite low in 2014 due to freeze damage.

Discussion

Ours is the first study of ground management systems in Turkish kiwi orchards. Therefore, the present findings will be discussed with the results of similar studies with other fruit species. Present cover crop treatments had significant effects on quality parameters of kiwifruit. *F. arundinacea* and *V. villosa* treatments in particular increased fruit width, length, and weights.

Cover crops had significant effects on the quality parameters of the other fruit species. Işık et al. (2018) obtained the largest apple fruit weight, width, and TSS ratios from herbicide-treated plots, and the greatest fruit lengths were obtained from mechanical control plots. Among the cover crops compared in that study, *T. repens, F. arundinacea,* and *V. villosa* produced the highest quality fruit. Kühn and Pedersen (2009) also reported that cover crops improved apple fruit coloration, and the highest red-colored fruits (greater than 75%

Table 4. Effects of cover crops on kiwi fruit yield (kg·ha^{-1}) over three years.

Treatment	2012	2013	2014	Mean
T. repens	28278 abc[y]	13359 b	6064 a	15004 abc
F. rubra rubra	38456 a	13828 b	3117 bc	17358 a
F. arundinaceae	19925 bc	14687 b	3365 bc	11936 bcd
Tr+Frr+Fa mixture[z]	32709 ab	18750 ab	1541 c	16857 a
V. villosa	28291 abc	21328 a	2632 bc	16512 ab
T. meneghinianum	30311 ab	21406 a	4736 ab	17879 a
Herbicide control	27366 abc	16563 ab	1761 c	14352 abc
Mechanical control	19833 bc	5938 c	1302 c	8304 d
Weedy control	16223 c	1625 ab	1572 c	10703 cd

[z] Cover crop mixture: *T. repens* (40%), Frr: *F. rubra rubra* (30%), Fa: *F. arundinacea* (30%).
[y] Means within columns followed by common letters do not differ at the 5% level of significance, by LSD.

red color) were obtained from the plots with continuous grass cover. Muscas et al. (2017) studied cover crops in a grape vineyard and reported that a mixture of leguminous cover crops increased harvest sugar concentration as compared to soil tillage. Cover crop treatments also influenced anthocyanins and polyphenol concentrations. Xi et al. (2011) reported that cover crop treatments improved grape polyphenol content and wine quality (Xi et al., 2011).

In the present study, the highest yields were obtained from *T. meneghinianum, F. rubra rubra,* and a mixture of perennial species. As compared to the control treatments, cover crop treatments improved kiwi yields (Table 4). Low yield for mechanical control plots were mostly attributed to root damage. Low yields in 2014 were attributed to freeze injury.

Present findings of the effects of cover crops on yield support previous studies. Demir et al. (2019) reported that *Vicia* spp. cover crops generally increased yield in an apricot orchard established over clay soils as compared to the control treatments without cover crops. Yield largely depends on organic matter levels of the soils (Demir et al., 2019; Demir and Işik, 2019). Even with the use of cover crops, organic fertilizers are needed for high yields and tree vigor (Sánchez et al., 2007). The organic matter directly improves soil physicochemical and biological quality parameters and then improves yield levels accordingly (Franzluebbers, 2002). Yields are also related to species and cultivars. Cover crop species also influence yield (Chalk, 1998). Işık et al. (2018) reported that cover crop treatments improved apple tree growth and development, as well as yield in an organic apple orchard as compared to control plots without cover crops. In brief, present cover crop treatments increased yields, and highest yields were achieved with *V. villosa.* Similar to other studies, weeds significantly reduced kiwi yield and quality. Therefore, an efficient weed control strategy should be practiced in kiwi orchards. Herbicides are commonly used for weed control in kiwi orchards. However, herbicides may have severe negative impacts on the environment and trade of kiwi fruit. Therefore, there is a need for alternative weed control methods to minimize herbicide uses in kiwi orchards.

Conclusion

In the present study, cover crops were evaluated for ground management (live mulching) in kiwi orchards. Results suggest that cover crops can be used as a sustainable ground management practice in kiwi orchards. Cover crops between tree rows may reduce dependence on herbicides and also mitigate the adverse impacts of herbicides on the environment. For this purpose, winter-sown annual *V. villosa* could be used as a cover crop between kiwi trees in regions with relatively dry summers. *V. villosa* should be sown in autumn, incorporated into the soil at the end of May to the beginning of June. Such a practice may improve soil organic matter content and thus fruit yield and quality. A canopy of *V. villosa* over the ground in autumn and winter will suppress the emergence of weeds. When incorporated into the soil, decomposed *V. villosa* residues will also prevent the emergence of weeds through allelopathy for a month. In regions like the Eastern Black Sea with high precipitation levels and no cost of irrigation and competition for water, *F. arundinacea* and *T. Repens*-like perennial cover crops or a mixture of these species could reliably be used while the sowing of cover crops, at least 1.0 m space should be provided from the trees to prevent damaging roots and to minimize competition for nutrients and water.

Cover crops are being used in some large commercial apple orchards, and widespread adoption in Turkey is expected in the near future. Since this is the first study of cover crops in Turkish kiwi orchards, this information should be provided to growers, and demonstration orchards should be established by the public and private sector to promote widespread use of cover crops in kiwi orchards.

Present findings revealed that cover crops could be used as an alternative and efficient tool in weed control. The results also revealed that the cover crops did not increase the yield losses when compared to other weed control methods.

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