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Effects of non-living mulches and metribuzin on yield and yield components of tomato (*Lycopersicon escolentum* cv. CH)

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ABSTRACT- To compare the effects of six types of non-living mulches (wheat straw, sawdust, coco peat, peat moss, transparent and black plastic) with metribuzin on yield and yield components of tomato cv "CH" and the weed control efficiency, a study was conducted in a randomized complete block design with three replications at School of Agriculture, Shiraz University in 2012. Plots without mulch (weedy and weed free) were considered as control. The highest and the lowest tomato dry weight accumulation was observed in the black plastic mulch (728.98 g m^{-2}) and weedy treatment (126.22 g m^{-2}), respectively. The highest number of fruits (marketable plus unmarketable fruits) per plant (208.33) under black plastic mulch treatment was observed at harvest time. Tomato yield in plots covered with transparent plastic and black plastic were 20.93, 8.31 kg m^{-2}, respectively and were significantly different from those treated with herbicide (6.06 kg m^{-2}). Weed control efficacy evaluation showed that black (82.23%) and transparent (86.23%) plastic were not significantly different from metribuzin (84.59%). Application of non-living mulches produced tomatoes of higher quality and quantity.

INTRODUCTION

Weeds adversely affect tomato (*Lycopersicon escolentum* L.) production. At the beginning of growing season, this crop is strongly influenced by the competition from weeds causing yield reduction (Wilson et al., 2001). Since tomato seedlings are usually transplanted to the field, they do not have strong rooting system to compete with weeds for water before being fully established and therefore are seriously affected by weeds (Law et al., 2006; Radics et al., 2006). Additionally, weeds can host a variety of pests and diseases in tomato fields, making weed control and removal necessary. Currently, weeds in tomato field are controlled using herbicides that are not actually stable and have detrimental effects on the environment (Mohammadi, 2013).

Nowadays different types of pre-planting, post-planting and post emergence herbicides are being widely used (Soltani et al., 2005). Yet, tomato seedlings are still very vulnerable at transplanting time and herbicides can cause substantial damages, and eventually lead to a considerable amount of yield loss. The use of herbicides at flowering time may also result in loss of tomato flowers (Shogren and Hochmut, 2004; Rashdi et al., 2009). The usual herbicides in tomato fields include metribuzin (Sencor), metolachlor and trifluralin. Currently, farmers are interested in alternative strategies to control weeds. To produce healthy food and minimize damage to the environment, more attention has been placed on non-chemical weed control methods. Non-living mulches (organic and inorganic) are used as non-chemical methods of weed control. These types of mulches cover the ground, increase soil temperature and prevent weed seeds to germinate. Therefore, this study aimed to compare the effects of non-living mulches (organic and inorganic) with herbicide (metribuzin) on yield, yield components of tomato and weed control.

MATERIALS AND METHODS

A field experiment was conducted during 2012 growing season at the research field in School of Agriculture, Shiraz University (35° 52' E, 40° 29' N, altitude 1810 m a. s. l), Shiraz, Iran. Land preparation practices included plowing, disking and ridging. Each plot measured 3 m x 6 m had 44 plants as this density is especially for fresh use. Each plot consisted of four 6 m long rows spaced 50 cm apart. Soil texture was the clay loam. Electrical conductivity and pH were 1.2 dS m^{-1} and 7.1, respectively. The experiment was arranged in a randomized complete block design (RCBD) with three replications. Treatments included six different types of non-living mulches (organic and inorganic) i.e., black plastic, transparent plastic, wheat straw, peat moss, coco peat, and sawdust and metribuzin as the chemical weed control method along with weedy and weed-free treatments as control. Metribuzin was applied five weeks after transplanting. Six week-old tomato seedlings (cv. CH) were transplanted into each plot on June, 30, 2012. The plots were fertilized with 20:20:20 (N, P_2O_5, K_2O) at a rate of 166 kg ha^{-1}. Irrigation was conducted by drip irrigation system twice a week. A water dropper interval of 20 cm was used. The average flow of the water dropper was 1 L/h. Tomatoes were harvested thirteen weeks after transplanting and total yield (kg m^{-2}), number of fruits per plant, leaf area index and above ground biomass were determined. The two middle rows of each plot (22 plants) were used to determine total yield, number of fruits per plant (marketable plus unmarketable fruits), leaf area index and biomass of tomato plants. Weed control efficiency (WCE) was calculated using the following equation (Bangi et al., 2014)

Differences among treatments were estimated by analysis of variance (ANOVA) using the SAS program (SAS institute, ver. 9.1). All the data were analyzed with statistical test ($SD_{5\,\%}$) Turkey's-test.

RESULTS AND DISCUSSION

Leaf Area Index (LAI)

Results indicated that LAI was significantly affected by treatments (Table 1). The black plastic had the highest effect on tomato LAI at harvest time (18651.86) while the lowest LAI was observed when sawdust treatment was applied (4114.87) (Table 2). Tomato LAI was affected significantly by herbicide treatment compared to non-living mulches.

Ahmad et al. (2011) reported that leaf area was significantly affected by different mulch materials and maximum leaf area was produced by the chili plant when transparent polyethylene mulch was applied and it was statistically similar to black polyethylene mulch treatment. The average leaf area was observed in rice straw (5.35 cm^2) mulch that was statistically analogous to wheat straw (5.20 cm^2). The lowest leaf area was observed in control treatment which was similar to sugarcane pug. The improvement in leaf area is likely due to the maintenance of moisture and increase in soil temperature. Similarly, Hallidri (2001) reported that polyethylene mulch increased the vegetative growth of cucumber.

Height

In this study, the effects of the treatments on the height of tomato plants were assessed weekly from transplanting to harvest. The highest plants were observed in plots treated by black plastic, while other treatments had variable effects on the growth of plants during this period (Table 3). Results indicated that plant height under mulch treatments was significantly higher than that in the weedy treatment at harvest time (Table 2). The highest and the lowest plant height were achieved under black plastic treatment (77.94 cm) and weedy treatment (33.81 cm) at harvest time, respectively (Table 2).

$$\text{WCE} = \frac{\text{Dry weight of weeds in weedy plot} - \text{Dry weight of weeds in each plot}}{\text{Dry weight of weeds in weedy plot}} \quad (1)$$

Table 1. Analysis of variance (ANOVA) for some measured parameters in tomato at harvest time

Source of variations	df	Mean-square					
		LAI	Plant Height	Dry Weight	Number of fruit	Total Yield	Weed control efficiency
Blocks	2	0.02^{ns}	1.44^{ns}	13.11^{ns}	16.59^{ns}	0.08^{ns}	6.14^{ns}
Treatment	8	0.75^{**}	457.16^{**}	123047.45^{**}	12646.45^{**}	101.23^{**}	2871.32^{**}
Error	16	0.06	0.35	11.96	13.34	0.17	5.27
C.V		2.91	1.05	1.09	3.27	5.31	3.60

* = significant at P≤ 0.05; ** = significant at P≤ 0.01; Ns = not significant

Table 2. Response of tomato traits to different kinds of mulches and metribuzin at harvest time

	Black plastic	Peat moss	weedy	Transparent plastic	Sawdust	Metribuzin	Coco peat	Weed-free	Wheat straw
LAI	18651.86a	6248.50e	3126.67h	7730.79d	4114.87g	8620.46c	5496.75f	13508.29b	4895.68f
Height (cm)	77.94a	55.32d	33.81f	53.95d	48.31e	55.26d	58.52c	69.28b	55/66d
Dry weight ($g.m^{-2}$)	728.98a	201.90e	126.20i	436.86c	140.82h	405.55d	188.96f	451.86b	172.38g
Number of fruits ($no.pt^{-1}$)	208.33a	90.00e	23.33i	129.33d	51.33h	186.33b	78.00f	170.66c	67.33g
Total yield ($kg.m^{-2}$)	20.93a	7.90c	1.24f	8.31c	3.4e	6.06d	5.11d	12.33b	5.72d

Different letters indicate significant differences for each row at P≤ 0.05 using Tukey's test

Table 3. Comparison of treatment effects on the height and number of fruit per plant in the twelve-week trial

Weeks	Black plastic	Peat moss	weedy	Transparent plastic	Sawdust	Metribuzin	Coco peat	Weed-free	Wheat straw
Height (cm)									
First	13. 00a	12. 98a	12. 95a	12. 88a	13. 02a	13. 04a	13. 01a	12. 94a	12. 99a
Second	13. 00a	12. 98a	12. 95a	12. 88a	13. 02a	13. 04a	13. 01a	12. 94a	12. 99a
Third	16. 10a	15. 29abc	14. 66c	15. 60ab	14. 91bc	14. 81bc	15. 34abc	15. 97a	14. 99bc
Fourth	25. 59a	24. 17abcd	23. 44d	24. 95abe	23. 58c	24. 00bcd	24. 75abcd	25. 04ab	24.50abcd
Fifth	36. 43a	33. 16b	25. 26de	27. 29de	25. 19bc	31. 23cd	29. 07b	32. 75d	28. 03e
Sixth	40. 04a	36. 96b	26. 36g	28. 25f	29. 25ef	32. 17d	30. 08e	35. 31c	29. 53e
Seventh	46. 79a	38. 03b	27. 36e	28. 55e	32. 81c	33. 46c	34. 47c	38. 21b	30. 88d
Eighth	51. 34a	39. 73c	28. 45h	31. 49g	36. 79de	34. 70f	37. 36d	43. 46b	35. 24ef
Ninth	55. 80a	41. 55c	29. 59e	34. 98d	40. 21c	38. 31d	40. 49c	48. 42b	38. 35d
Tenth	67. 64a	43. 14cd	31. 48g	41. 07ef	42. 98cd	40. 25f	43. 89c	55. 17b	42. 22de
Eleventh	71. 98a	46. 62de	32. 97f	46. 88cde	45. 01e	46. 85de	48. 87c	60. 25b	47. 95cd
Twelfth	75. 47a	49. 98e	33. 26g	51. 40d	46. 87f	51. 19de	53. 15c	65. 48b	51. 90cd
Number of fruits (no. pt^{-1})									
First	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00
Second	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00
Third	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00
Fourth	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00
Fifth	19. 66a	0. 00c	0. 00c	3. 33b	0. 00c	0. 00c	0. 00c	3. 00bc	0. 00c
Sixth	47. 66a	5. 00ab	0. 00b	38. 00ab	0. 00b	0. 00b	0. 00b	6. 66ab	0. 33b
Seventh	90. 66a	24. 00c	7. 00f	19. 66cd	12. 33ef	40. 66b	17. 00de	25. 33c	17. 33de
Eighth	203. 66a	86. 33e	21. 00i	123. 00c	47. 00h	184. 00b	73. 66f	105. 00d	61. 00g
Ninth	203. 66a	86. 33e	21. 00i	123. 00d	47. 66h	184. 00b	73. 66f	168. 33c	61. 00g
Tenth	204. 00a	86. 66e	21. 00h	126. 00d	49. 33g	184. 33b	75. 00f	168. 33c	65. 00f
Eleventh	206. 66a	89. 33e	22. 00h	127. 33d	50. 33g	185. 33b	76. 66f	170. 00c	65. 66f
Twelfth	207. 00a	90. 00e	22. 00h	128. 00d	50. 33g	186. 33b	78. 00f	170. 66c	67. 33f

Different letters indicate significant differences for each row at P≤ 0.05 using Turkey’s test

Application of black plastic, weed-free, transparent plastic, peat moss, wheat straw, metribuzin, coco peat and sawdust showed 1.30, 1.04, 0.59, 0.63, 0.64, 0.63, 0.73 and 0.42% increase in plant height, respectively, in comparison with the weedy control treatment (Table 2). This might be due to the availability of moisture and increased temperature during the growing season. These findings are in agreement with those of Olabode et al. (2007) who found that the use of polyethylene mulch increased plant height in okra (*Abelmoschus esculentus*). Thakur et al. (2000) reported that plastic, lantana leaves and grass mulches significantly maintained higher growth parameters of *Capsicum annuum* as compared with un-mulched treatments. Singh (2005) obtained the highest plant height (79.40 cm) in tomato with the application of black polyethylene mulch as compared to other mulches and control.

Dry Weight

The results showed that application of mulch significantly increased tomato dry weight. The highest and the lowest dry weight were recorded with the black plastic mulch application (728.98 g m^{-2}) and weedy treatment (126.22 g m^{-2}) at harvest time, respectively (Table 2). Results showed that black plastic, weed-free, transparent plastic, peat moss, metribuzin, wheat straw, coco peat and sawdust, caused 4.77, 2.58, 2.46, 0.59, 2.21, 0.36, 0.49 and 0.11% increase in dry weight, respectively (Table 2). In comparison to metribuzin (405.55 g m^{-2}) black plastic mulch on the basis of 44.36% increased dry weight of tomato plants and these treatments showed significant differences. It was also noticeable that the effects of all non-living organic mulches were lower than the black and transparent plastic mulches on biomass accumulation (Table 2). Singh (2005) examined the effects of a number of mulches on dry matter of tomato and found that the highest and the lowest dry matter yield were obtained in black plastic and straw mulch treatments. Masiunas et al. (2003) observed that maximum value of highest biomass of basil (*Ocimum basilica*) was recognized in black plastic mulch than other treatments.

Number of Fruits Per Plant

The results of data analysis based on the average number of fruits per plant (marketable plus unmarketable fruits) at harvest time (week thirteen) showed that there was no significant difference between treatments at the 1% level (Table 1). In this study, the effect of treatments on the number of fruits per plant was evaluated in two forms: the first was from the beginning of transplanting to harvest time while the second was measured only at the harvest time. The black plastic mulch and weedy treatments had the highest and the lowest fruit formation, respectively throughout the experiment. In addition to the black plastic mulch (47.66) in week six, transparent plastic mulch (38.00), weed free treatment (6.66) and peat moss (5.00) treatments had the highest impact on the rate of fruit emergences per plant (Table 3). The weekly assessment of fruit number per plant showed that there were no fruits from the first to the fourth week. The first fruits appeared in plots treated by black plastic mulch and weed free treatment in the fifth week. The first fruits appeared in plots treated by black plastic mulch and also in the plots under weed free treatment in the fifth week. The number of fruits on tomato plants in plots treated with black plastic mulch (19.66) was 5.90 times higher than the number of fruits on plants treated with transparent plastic mulch (3.33) and the weed free treatment (3.00) in each plot (Table 3). The seventh week was a turning point in the production of fruits on tomato plants when fruits were observed in all plots. Remarkably, the plots under metribuzin treatment were apt to produce fruits in this week (Table 3). During the harvesting time, the number of fruits per plant was exactly identical to that of weeks 10-12 (Table 2). The effectiveness of inorganic mulches in this study was higher in the formation of fruits per plant compared to non-living organic mulches. In addition, black plastic mulch and weed free treatment showed a much higher incidence, when compared with metribuzin (Table 2). Awodoyin et al. (2007) studied the effects of several kinds of non-living mulches on the performance of tomato plants in terms of the average number of fruits per plant. The number of fruits per plant in the plots under the influence of black plastic mulch was much higher than the number of fruits obtained in other plots, even though those plots were weed free. Nagalakshmi et al. (2002) obtained the maximum number of fruits per plant (97.67) with the application of black polyethylene mulch compared to organic mulch and no mulch.

Total Yield

The highest yield per unit area was obtained from black plastic mulch treatment (20.93 kg m^{-2}) while the lowest (1.24 kg m^{-2}) was observed in the plots under weedy treatment (Table 2). Overall, in comparison with the weedy treatment, black plastic mulch (15.87%), weed free treatment (8.94%), transparent plastic mulch (5.70%), peat moss (5.37%), metribuzin (3.88%), wheat straw (3.61%), coco peat (3.12%) and the sawdust (1.74%) increased the total yield of tomato per unit area (Table 2). In the group of organic mulches, peat moss (7.90 kg m^{-2}) in comparison with metribuzin (6.06 kg m^{-2}) increased total yield by 23.29% while they had significant difference. Black plastic mulch significantly increased the production of tomato while other treatments had no considerable effect on tomato production. This is mainly because black plastic mulch reduces the evaporation from the soil surface and causes better plant growth which is governed by soil temperature with minimum fluctuations, as well as soil moisture. These results confirm the findings of Singh (2005) in tomato, Locher et al. (2005) in sweet pepper (*Capsicum annuum*), Ganhi et al. (2006) in tomato, Arancibia et al. (2008) in watermelon, Diaz Perez (2009) in broccoli (*Brassica oleracea*) and Anzalone et al. (2010) in tomato. The above results were also in agreement with those of Ibarra et al. (2001) in muskmelon (*Cucumis melo*).

Weed Control Efficiency

Results showed that all treatments (mulches and metribuzin) increased weed control efficiency compared to the weedy treatment (Fig. 1). The black (82.23%) and transparent (86.23%) plastic mulches compared to metribuzin (84.59%) were not statistically different. It also became clear that the inorganic mulches compared to the organic ones had a greater ability to inhibit weeds (Fig. 1). Black plastic, weed free, transparent plastic, peat moss, metribuzin, wheat straw, coco peat and sawdust in comparison with the weedy treatment increased weed control efficacy by 83.23, 100.00, 86.23, 33.70, 84.59, 56.80, 62.38 and 66.16%, respectively (Fig. 1).This result shows that plastic mulches and herbicide had an effective impact on weed control than organic mulches. The lowest weed control efficacy was observed under grass mulch and the highest under plastic mulch (Awodoyin et al., 2007).

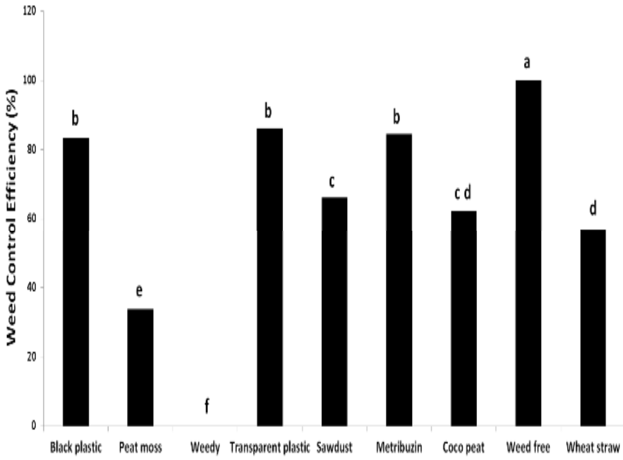

Fig. 1. Response of weed control efficiency to different kinds of mulches and metribuzin at harvest time (Tukey's test 5 %)

CONCLUSIONS

The organic mulches increase organic matter and improve soil structure. However, they do not provide the same soil warming benefits as plastic mulches. The plastic mulches can enhance plant growth and development, increase yield, decrease soil evaporation and nutrient leaching, reduce incidence of pests and weeds, and improve fruit cleanliness and quality.

According to the results, the transparent and black plastic mulches had more positive impacts on weed control and yield of tomato than metribuzin and other mulches. Application of non-living mulch can lead to high yield and quality tomato products. Also according to the results it seems that combined application of mulches with herbicides can be a practical and effective option for tomato production.

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اثرات مالچ‌های غیرزنده (ارگانیک و غیرارگانیک) و علف‌کش متریبوزین بر عملکرد و اجزای عملکرد گوجه‌فرنگی (*Lycopersicon escolentum* cv. CH)

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پلاستیک شفاف
مهار علف‌هرز

چکیده- به منظور مقایسه اثرات شش نمونه مالچ شامل مالچ پلاستیک شفاف، پلاستیک مشکی، کاه‌وکلش گندم، خاک اره،کوکوپیت و پیت‌ماس با علف‌کش متریبوزین بر عملکرد و اجزای عملکرد گوجه‌فرنگی رقم "CH" و مهار علف‌های‌هرز آزمایشی در قالب طرح بلوک کامل تصادفی با نه تیمار در سه تکرار در دانشکده کشاورزی دانشگاه شیراز در سال ۱۳۹۱ صورت پذیرفت. پلات‌های بدون مالچ (حضور علف‌هرز و بدون علف‌هرز) به عنوان شاهد استفاده شدند. بیشترین و کمترین تجمع وزن خشک گوجه‌فرنگی به ترتیب درکرت‌های تحت تاثیر مالچ پلاستیک مشکی (۷۲۸/۹۸ گرم در مترمربع) و تیمار حضور علف‌هرز (۱۲۶/۲۲گرم در مترمربع) مشاهده شد. بیشترین تعداد میوه در هر بوته (۲۰۸/۳۳) در تیمار مالچ پلاستیک مشکی در زمان برداشت محصول مشاهده شد. عملکرد گوجه‌فرنگی به ترتیب درکرت‌های تیمار شده با مالچ‌های پلاستیک شفاف و مشکی ۲۰/۹۳ و ۸/۳۱ کیلوگرم در مترمربع بود که با علف‌کش متریبوزین (۶/۰۶ کیلوگرم در هکتار) اختلاف معنی‌داری نشان داد. بررسی کارآیی کنترل علف‌های‌هرز نشان داد که مالچ‌های پلاستیک مشکی (۸۲/۲۳ درصد) و شفاف (۸۶/۲۳ درصد) با علف‌کش متریبوزین (۸۴/۵۹ درصد) از این نظر دارای اختلاف آماری معنی‌داری نبودند. بررسی‌ها نشان داد که کاربرد مالچ‌های غیرزنده سبب تولید محصول گوجه‌فرنگی بیشتری شد.