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Effect of Mulch and Tillage on Yield and Quality of Tomato (*Lycopersicon esculentum*)

Majid Rashidi and Karim Arabsalmani

Greenhouse Cultivation Research Department,
Tehran Agricultural and Natural Resources Research and Education Center, AREEO, Varamin, Iran

Abstract: Field experiments were carried out to study the effect of plastic mulch and tillage method on yield, yield components and quality of tomato (*Lycopersicon esculentum*) during 2013 and 2014 growing seasons. Mulch levels in the study were plastic-mulching (PM; black plastic mulch) and no-mulching (NM) and tillage treatments were conventional tillage (CT; moldboard plowing + two passes of disk harrowing), minimum tillage (MT; one pass of disk harrowing) and no-tillage (NT). Yield, yield components (number of plants per hectare, NPPH; number of fruits per plant, NFPP; fruit weight, FW; fruit length, FL; fruit diameter, FD) and one quality parameter (total soluble solids, TSS) were determined for all treatments. Results indicated that mulch levels and tillage methods significantly ($P \leq 0.05$) influenced yield, yield components and TSS. Results also showed that NPPH and NFPP were the most important yield components explaining yield difference under the different mulch levels and tillage methods. The maximum NPPH (10481), NFPP (17.6) and as a result yield (11.4 t ha^{-1}) were observed when PM was applied, while maximum values of FW (67.5 g), FL (65.3 mm), FD (56.8 mm) and TSS (6.46%) were noted in case of NM plots. In contrast, minimum NPPH (7350), NFPP (14.2) and hence yield (7.36 t ha^{-1}) were obtained with NM, while the minimum values of FW (61.1 g), FL (63.3 mm), FD (55.9 mm) and TSS (5.21%) were noted in case of PM treatment. Moreover, the maximum NPPH (11438), NFPP (20.4) and consequently yield (14.1 t ha^{-1}) were observed with CT, while maximum values of FW (67.8 g), FL (68.9 mm), FD (58.9 mm) and TSS (6.35%) were noted NT plots. Conversely, minimum NPPH (6275), NFPP (12.2) and hence yield (5.24 t ha^{-1}) were obtained with NT, while the minimum values of FW (60.6 g), FL (60.1 mm), FD (53.1 mm) and TSS (5.41%) were noted in case of CT treatment. On the whole, for reaching the highest yield and enhanced quality of tomato in the arid lands of Iran integrated use of mulch and tillage can be recommended.

Key words: Mulch · Tillage · Tomato · Yield · Yield components · Quality · Arid lands

INTRODUCTION

Tomato (*Lycopersicon esculentum*) is one of the most important vegetable crops of Iran and is well adapted to its soil and climatic conditions. Tomato ranks first in cultivated area and production among all other vegetables in Iran. The average national production of tomato for the last two years was 4.4 million tones [1].

As the world becomes increasingly dependent on the production of irrigated lands, irrigated agriculture faces serious challenges that threaten its suitability. It is prudent to make efficient use of water and bring more area under irrigation through available water resources. This can be achieved by introducing advanced and sophisticated methods of irrigation and improved water management practices [2]. Among the management practices for increasing water use efficiency one of them is mulching. Any material spread on the surface of soil to protect it from rain drop, solar radiation or evaporation is called mulch. Different types of materials like wheat straw, rice straw, plastic film, grass, wood, sand, etc. are used as mulch [3, 4]. Mulch provides a better soil environment [5], moderates soil temperature [6, 7], increases soil porosity and water infiltration during intensive rain [8] and controls runoff and soil erosion [9].

Application of plastic mulch soon after planting is sometimes beneficial. The use of polyethylene film spread over the planted crop rows serves to conserve moisture and control weeds [5]. Plastic mulches directly affect the microclimate around the plant by modifying the radiation

Corresponding Author: Dr. Majid Rashidi, Ph.D., Greenhouse Cultivation Research Department,
Tehran Agricultural and Natural Resources Research and Education Center, AREEO, Varamin, Iran.
E-mail: majidrashidi81@yahoo.com & m-rashidi@areeo.ac.ir.

budget of the surface and decreasing the soil water loss [10]. The color of plastic mulch largely determines its energy-radiation behaviour and its influence on the microclimate around a plant [11]. Color also affects the surface temperature of the mulch and underlying soil temperature. Black plastic mulch, the predominant color used in crop production, is an opaque black body absorber and radiator [11, 12].

Soil tillage is one of the very important factors that affect soil physical properties and yield [13, 14]. Khurshid *et al.* [3] reported that among the crop production factors, tillage contributes up to 20%. Tillage method affects the sustainable use of soil resources through its influence on soil properties [15], i.e. proper tillage practices can improve soil related constrains, while improper tillage may cause a range of undesirable processes such as destruction of soil structure, accelerated erosion, depletion of organic matter and fertility and disruption in cycles of water, organic carbon and plant nutrients [16]. Use of excessive and unnecessary tillage operations is harmful to soil. Therefore, currently there is a significant interest and emphasis on the shift to the conservation tillage and no-tillage methods for the purpose of controlling soil erosion [17].

Most of the tomato area in Iran is under conventional tillage [1]. Conventional tillage practices modify soil structure by changing its physical properties such as soil bulk density, soil penetration resistance and soil moisture content [13, 14]. Annual disturbance and pulverizing caused by conventional tillage produce a finer and loose soil structure as compared to conservation and no-tillage methods which leave soil intact [18, 19]. This difference results in change number, shape, continuity and size distribution of the pores network, which controls the ability of soil to store and transmit air, water and agricultural chemicals. This also improves porosity and water holding capacity of the soil. This all leads to a favorable environment for crop growth and nutrient use [3, 20].

On the other hand, conservation tillage methods often result in decreased pore space [21], increased soil strength [22] and stable aggregates [23]. The pore network in conservationally tilled soil is usually more continuous because of earthworms, root channels and vertical cracks [24]. Therefore, conservation tillage may reduce disruption of continuous pores. Reddy *et al.* [25] quantified the amount of carbon dioxide (CO_2) released from soil as a result of different tillage methods. They observed 37% higher CO_2 efflux from conventionally tilled soils compared to no-till soils which represents higher carbon sequestration in no-till soils. However, the results of conservation tillage and no-tillage methods are contradictory [17]. Conservation tillage and no-tillage methods in arid lands of Iran had an adverse effect on yields of some crops [26]. Conversely, while comparing conventional tillage method to conservation tillage and no-tillage methods Chaudhary *et al.* [27] concluded that higher moisture preservation and 13% more income were obtained in case of no-tillage.

At this time, a wide range of farming systems are being used in Iran without evaluating their effects on yield and yield components of many crops as well as tomato. Therefore, the present investigation was planned to determine the effect of black plastic mulch and different tillage methods on yield, yield components and one quality parameter of tomato in the arid lands of Iran.

MATERIALS AND METHODS

Research Site: This study was carried out at the Research Site of Tehran Province Agricultural and Natural Resources Research Center, Varamin, Iran on a sand loam soil for two successive growing seasons (2013 and 2014). The research site is located at latitude: 35° 19' N, longitude: 51° 39' E and altitude: 1000 m in arid climate (150 mm rainfall annually) in the center of Iran. The soil of the research site is classified as an Aridisol (fine, mixed, active, thermic, typic haplocambids).

Weather Parameters: The mean monthly rainfall and temperature data of the research site during the years of study (2013 and 2014) are given in Fig. 1.

Soil Sampling and Analysis: To determine soil physical and chemical properties of the research site, a composite soil sample (from 18 points) was collected from 0-30 cm depth 30 days before transplanting during the study years. Soil sample was analyzed in the laboratory for N, P, K, Fe, Zn, Cu, Mn, B, EC, pH, organic carbon, particle size distribution and dry bulk density. Details of soil physical and chemical properties of the research site are given in Table 1.

Field Methods: A split plot experiment was laid out in a randomized complete block design (RCBD) with three replications to randomize the mulch levels and tillage methods in the main and sub-plots, respectively. The experiment comprised of two mulch levels, i.e. plastic-mulching (PM; black plastic mulch) and no-mulching

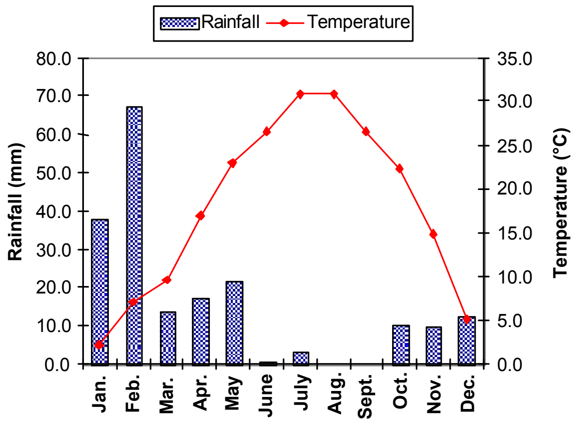

Fig. 1: Mean monthly rainfall and temperature (mean of 2013 and 2014)

Table 1: Soil physical and chemical properties of the research site (mean of 2013 and 2014)

Soil characteristics	Values
Texture	Sand loam
Sand (%)	54.0
Silt (%)	28.0
Clay (%)	18.0
Bulk density (Mg m^{-3})	1.51
EC (dS m^{-1})	2.90
pH	8.00
OC (%)	0.50
Total N (%)	0.06
P (ppm)	9.20
K (ppm)	272
Fe (ppm)	2.82
Zn (ppm)	2.06
Cu (ppm)	0.90
Mn (ppm)	8.20
B (ppm)	2.06

(NM) and three tillage methods, i.e. conventional tillage (CT; one pass of moldboard plow to depth of 15 cm + two passes of disk harrowing), minimum tillage (MT; one pass of disk harrowing) and no-tillage (NT; zero tillage activity). The treatments were carried out on the same plots in the 2013 and 2014 growing seasons. The size of each plot was 10.0 m long and 6.0 m wide. A buffer zone of 5.0 m spacing was provided between plots. There were two furrows in each plot (even in no-till plots). The furrows had 10.0 m long, 75 cm wide and 50 cm depth. In both growing seasons, one of the most commercial varieties of tomato cv. Early Urbana was transplanted manually on both sides of each furrow by keeping plant to plant distance 50 cm (totally there were four rows per plot). Before transplanting, recommended levels of N (350 kg ha^{-1}), P (100 kg ha^{-1}) and K (50 kg ha^{-1}) were used as Urea, TSP (triple super phosphate) and SOP (sulphate of potassium), respectively. They were incorporated in CT and MT and surface applied in NT. Trifluralin (0.75 L ha^{-1}) was also applied for weed control before tomato transplanting. Tomato was transplanted on 5th May when the soil was well irrigated in all treatments. Black plastic-film measuring 10.0 m long × 50 cm wide and 0.25 mm thick was used to cover the experimental beds (raised beds, 25 cm high) of appropriate plots and was held down with forked sticks and pegs to prevent it from been blown away by the wind. This was done one week after transplanting. During the growing season, the insecticides and fungicides were applied according to general local practices and recommendations. All other necessary operations except those under study were kept normal and uniform for all the treatments.

Observation and Data Collection: Tomatoes were harvested three times (23 July, 12 August and 31 August, respectively) and standard procedures were adopted for recording the data on yield and yield components. Yield, number of plants per hectare (NPPH) and number of fruits per plant (NFPP) were determined by counting plants and harvesting fruits of the two middle rows of each plot. Other parameters, i.e. fruit weight (FW), fruit length (FL), fruit diameter (FD) and total soluble solids (TSS) were determined from the 20 samples taken randomly from harvested fruits of the two middle rows of each plot. The TSS of tomatoes was measured using an ATC-1E hand-held refractometer (ATAGO, Japan, 2005) at temperature of 20°C.

Statistical Analysis: All collected data were subjected to the Analysis of Variance (ANOVA) following Gomez & Gomez [28] using SAS statistical computer software. Moreover, means of the different treatments were separated by Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$.

RESULTS

Yield and yield components of tomato were significantly influenced by mulch levels (Table 2). Between two mulch levels PM plots recorded significantly higher yield (11.4 t ha^{-1}) compared to NM plots (7.36 t ha^{-1}). Similar trend was also observed in case of NPPH and NFPP. Significantly higher NPPH and NFPP were observed in PM plots (10481 and 17.6, respectively) compared to NM plots (7350 and 14.2, respectively).

Table 2: Mean squares from the analysis of variance of yield, yield components and quality parameter of tomato under different treatments (mean of 2013 and 2014)

		Mean square						
Source of variation	Degree of freedom	Yield	NPPH	NFPP	FW	FL	FD	TSS
Mulch level	1	75.07 *	44101701 *	52.02 *	184.3 *	17.01 *	3.029 *	7.044 *
Tillage method	2	119.6 *	40039826 *	104.8 *	78.22 *	116.6 *	52.70 *	1.354 *
Mulch level × tillage method	2	1.917 *	1506701 *	0.780 *	0.185^{NS}	0.034^{NS}	0.051^{NS}	0.421 *
Error	8	0.007	33003	0.120	0.092	0.293	0.185	0.028
C.V. (%)	---	0.91	2.04	2.18	0.47	0.84	0.76	2.86

NS = Non-significant

* = Significant at 0.05 probability level

(NPPH: number of plants per hectare; NFPP: number of fruits per plant; FW: fruit weight; FL: fruit length; FD: fruit diameter; TSS: total soluble solids)

Table 3: Means comparison for yield, yield components and quality parameter of tomato for different studied treatments using DMRT at 5% probability (mean of 2013 and 2014)

Treatments		Yield (t ha^{-1})	NPPH	NFPP	FW(g)	FL(mm)	FD(mm)	TSS(%)
Mulch level	PM	11.4 a	10481 a	17.6 a	61.1 b	63.3 b	55.9 b	5.21 b
	NM	7.36 b	7350 b	14.2 b	67.5 a	65.3 a	56.8 a	6.46 a
$LSD_{5\%}$	---	---	---	---	---	---	---	
Tillage method	CT	14.1 a	11438 a	20.4 a	60.6 c	60.1 c	53.1 c	5.41 c
	MT	8.84 b	9033 b	15.0 b	64.4 b	63.9 b	57.1 b	5.76 b
	NT	5.24 c	6275 c	12.2 c	67.8 a	68.9 a	58.9 a	6.35 a
$LSD_{5\%}$	0.111	241.9	0.461	0.404	0.721	0.573	0.223	

Means in the same column with different letters differ significantly at 0.05 probability level according to DMRT.

(PM: plastic-mulching; NM: no-mulching; CT: conventional tillage; MT: minimum tillage; NT: no-tillage; NPPH: number of plants per hectare; NFPP: number of fruits per plant; FW: fruit weight; FL: fruit length; FD: fruit diameter; TSS: total soluble solids)

Table 4: Means comparison for yield, yield components and quality parameter of tomato for mulch level and tillage method combinations using DMRT at 5% probability (mean of 2013 and 2014)

Mulch level × tillage method		Yield (t ha^{-1})	NPPH	NFPP	FW(g)	FL(mm)	FD(mm)	TSS(%)
PM	CT	16.1 a	12850 a	21.7 a	57.6 f	59.2 f	52.6 e	5.00 e
	MT	11.5 c	11158 b	16.8 c	61.2 e	62.9 d	56.6 c	5.21 de
	NT	6.78 d	7433 d	14.2 d	64.4 c	67.9 b	58.6 a	5.43 d
NM	CT	12.2 b	10025 c	19.1 b	63.6 d	61.0 e	53.6 d	5.81 c
	MT	6.19 e	6908 e	13.2 e	67.6 b	64.8 c	57.6 b	6.31 b
	NT	3.70 f	5117 f	10.2 f	71.2 a	70.0 a	59.2 a	7.27 a
$LSD_{5\%}$		0.158	342.1	0.652	0.571	1.019	0.810	0.315

Means in the same column with different letters differ significantly at 0.05 probability level according to DMRT.

(PM: plastic-mulching; NM: no-mulching; CT: conventional tillage; MT: minimum tillage; NT: no-tillage; NPPH: number of plants per hectare; NFPP: number of fruits per plant; FW: fruit weight; FL: fruit length; FD: fruit diameter; TSS: total soluble solids)

In contradiction to above trend, NM plots recorded significantly higher FW, FL, FD and TSS compared to PM plots. Values of FW, FL and FD were 10, 3 and 2%, respectively higher in NM plots compared to that of PM plots. The quality parameter of tomato fruits, TSS was significantly higher in NM plots (6.46%) compared to that of PM plots (5.21%) (Table 3).

Moreover, tillage methods significantly influenced yield and yield components of tomato (Table 2). Among the three different tillage methods, the CT method recorded significantly higher yield (14.1 t ha^{-1}) compared to NT (5.24 t ha^{-1}) and MT (8.84 t ha^{-})[1] methods, respectively. Between the two conservation tillage methods MT method recorded significantly higher yield (69%) than NT method. A similar trend was also observed in case of NPPH and NFPP. Significantly higher NPPH and NFPP were observed in the CT plots (11438 and 20.4, respectively) compared to MT (9033 and 15.0, respectively) and NT (6275 and 12.2, respectively) plots. In contradiction to the above trend, NT and MT methods recorded significantly higher FW, FL, FD and TSS compared to the CT method. Between conservation tillage methods, the NT method recorded higher values for the above parameters. Values of FW, FL and FD were 12, 15 and 11%, respectively higher in NT plots compared to that of the CT plots. The quality parameter of tomato fruits, TSS was significantly higher in NT plots (6.35%) compared to that of the CT (5.41%) and MT (5.76%) plots (Table 3).

The interaction between mulch level and tillage method was also observed to be significant for yield, NPPH, NFPP and TSS. However, interaction of mulch level and tillage method for FW, FL and FD was not significant (Table 2). The study of mulch level and tillage method combinations showed that in both mulch levels yield, NPPH and NFPP had the highest value in case of the CT treatment and lowest value in case of NT treatment. The maximum mean value for yield (16.1 t ha^{-1}), NPPH (12850) and NFPP (21.7) was obtained in case of PM × CT combination and minimum mean value for yield (3.70 t ha^{-1}), NPPH (5117) and NFPP (10.2) was obtained in case of NM × NT combination. In addition, in both mulch levels yield, NPPH and NFPP was affected by tillage method in the order of CT > MT > NT (Table 4). Conversely, mean comparison of mulch level and tillage method combinations on FW, FL, FD and TSS indicated that in both mulch levels FW, FL, FD and TSS had the highest value in case of NT treatment and lowest value in case of the CT treatment. The maximum mean value for FW (71.2 g), FL (70.0 mm), FD (59.2 mm) and TSS (7.27%) was observed in case of NM × NT combination and minimum mean value for FW (57.6 g), FL (59.2 mm), FD (52.6 mm) and TSS (5.00%) was observed in case of PM × CT combination. Besides, in both mulch levels FW, FL, FD and TSS was affected by tillage method in the order of NT > MT > CT (Table 4).

DISCUSSION

In this study, the salient components of yield such as NPPH, NFPP, FW, FL, FD and a fruit quality parameter, i.e. TSS were studied to analyze the effect of different mulch levels and tillage methods on growth and yield of tomato. The statistical results of the study indicated that mulch level and tillage method significantly affected yield, NPPH, NFPP, FW, FL, FD and TSS during the study years. Results also showed that plastic mulch and tillage practices were beneficial in improving the growth and yield of tomato (Table 2).

The maximum value of NPPH (10481) and NFPP (17.6) was observed in PM plots, while maximum value of FW (67.5 g), FL (65.3 mm), FD (56.8 mm) and TSS (6.46%) was noted in NM plots. As NPPH and NFPP were the most important yield components explaining yield of tomato under different mulch levels, the maximum value of yield (11.4 t ha^{-1}) was observed in PM plots. Conversely, the minimum value of NPPH (7350) and NFPP (14.2) was obtained in case of NM plots, while the minimum value of FW (61.1 g), FL (63.3 mm), FD (55.9 mm) and TSS (5.21%) was noted in case of PM plots. In view of the fact that NPPH and NFPP were the most important yield components explaining yield of tomato under different mulch levels, the minimum value of yield (7.36 t ha^{-1}) was obtained in case of NM plots (Table 3). These results are in agreement with those of Anikwe *et al.* [5] and Aniekwe *et al.* [12] who concluded that black plastic mulching enhanced growth and yield of the plants in the arid lands. These results are also in line with the results reported by Khurshid *et al.* [3] and Glab & Kulig [8] that mulching increased soil porosity and reduced soil compaction. These results are also in agreement with those of Khurshid *et al.* [3], Seyfi & Rashidi [4], Sarkar & Singh [6] and Sarkar *et al.* [7] who concluded that mulching (especially black plastic mulch) reduced leaching of nutrients, reduced weed problems, reduced evaporation of soil water and increased water use efficiency. They also concluded that plastic mulch helped maintain optimum soil moisture and promoted excellent crop growth throughout the growing season.

The maximum value of NPPH (11438) and NFPP (20.4) was observed in case of the CT treatment, while maximum value of FW (67.8 g), FL (68.9 mm), FD (58.9 mm) and TSS (6.35%) was noted in case of NT treatment. As NPPH and NFPP were the most important yield components explaining yield of tomato under different tillage methods, the maximum value of yield (14.1 t ha^{-1}) was observed in case of the CT treatment (Table 3). These results are in agreement with those of Khurshid *et al.* [3], Keshavarzpour & Rashidi [13], Rashidi & Keshavarzpour [14], Iqbal *et al.* [17], Rashidi & Keshavarzpour [18], Rashidi *et al.* [19], Khan *et al.* [20] and Khan *et al.* [29] who concluded that conventional tillage can be associated with reduced soil penetration resistance, reduced soil bulk density, increased soil moisture preservation, improved soil structure, enhanced root-soil contact and better weed growth suppression which favorably affect root development, plant growth, plant population density, resulting in increased yield.

On the other hand, the minimum value of NPPH (6275) and NFPP (12.2) was obtained in case of NT treatment, while the minimum value of FW (60.6 g), FL (60.1 mm), FD (53.1 mm) and TSS (5.41%) were noted in case of the CT treatment. In view of the fact that NPPH and NFPP were the most important yield components explaining yield of tomato under different tillage methods, the minimum value of yield (5.24 t ha^{-1}) was obtained in case of NT treatment (Table 3). These results are in agreement with those of Hill [21], Bauder *et al.* [22] and Horne *et al.* [23] who concluded that no-tillage and conservation tillage methods can be associated with decreased pore space, increased soil penetration resistance, increased soil bulk density, decreased soil moisture conservation which adversely affect root development, plant growth and plant population density and consequently yield. These results are also in line with the results reported by Iqbal *et al.* [17] that no-tillage method can not compensate the adverse effect of fine texture, very low organic matter and an overall initial weak structure of the soil. These results are also in agreement with those of Keshavarzpour & Rashidi [13], Rashidi & Keshavarzpour [14] and Hemmat & Taki [26] who concluded that the no-tillage method in arid regions had an adverse effect on yield. As well, Reddy & Reddy [30] concluded that no-tillage needs extra nutrients in the form of crop residue to give similar yields to conventional tillage. They observed 18% higher yields in conventional tillage compared to no-tillage with similar quantity of nutrients. Conversely, they observed 21% higher yields in no-tillage plots compared to conventional tillage when extra crop residue was included in the form of winter cover crop. Hence future studies are needed to find the response of tomato to no-tillage along with higher nutrient dosage and residue cover.

CONCLUSION

For reaching the highest yield and enhanced quality of tomato in the arid lands of Iran integrated use of mulch and tillage can be recommended.

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