VOL. 5, NO. 4, JULY 2010 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

EFFECT OF PLASTIC MULCH AND TILLAGE METHOD ON YIELD AND YIELD COMPONENTS OF TOMATO (*Lycopersicon esculentum*)

Majid Rashidi[1], Mohammad Gholami[2] and Saeed Abbassi[2]
[1]Member of Young Researchers Club, Islamic Azad University, Takestan Branch, Iran
[2]Department of Agricultural Machinery, Faculty of Agriculture, Islamic Azad University, Takestan Branch, Iran
E-Mails: majidrashidi81@yahoo.com , m.rashidi@tiau.ac.ir

ABSTRACT

A field experiment was conducted at the Research Site of Tehran Province Agricultural and Natural Resources Research Center in Varamin, Iran to study the effect of black plastic mulch and different tillage methods on yield and yield components of tomato (*Lycopersicon esculentum*) during 2007 and 2008 growing seasons. Mulch levels in the study included 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 (plant population density, PPD; number of fruits per plant, NFPP; fruit weight, FW; fruit length, FL; fruit diameter, FD) and fruit 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 the yield, yield components and TSS. Results also showed that PPD and NFPP were the most important yield components explaining yield difference under the different mulch levels and tillage methods. The maximum PPD (10481 plants h^{-1}), 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 NM plots. In contrast, minimum PPD (7350 plants ha^{-1}), 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 PPD (11438 plants ha^{-1}), 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 PPD (6275 plants ha^{-1}), 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. As a result, plastic mulch and tillage have pronounced effect on yield, yield components and TSS of tomato in the arid lands of Iran.

Keywords: tomato, plastic mulch, tillage methods, yield, yield components, semi-arid, Varamin, Iran.

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 (Iranian Ministry of Agriculture, Statistical Yearbook, 2006). According to Agricultural Ministry of Iran the average national production of tomato for the last two years was 4.4 million tones. Although the use of improved varieties and fertilizers has increased tomato production to much extent, the full potential of crop production has not yet been achieved when compared to progressive countries.

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 (Zaman *et al.*, 2001). 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 (Khurshid *et al.*, 2006; Seyfi and Rashidi, 2007). Mulch provides a better soil environment (Anikwe *et al.*, 2007), moderates soil temperature (Sarkar and Singh, 2007; Sarkar *et al.*, 2007), increases soil porosity and water infiltration during intensive rain (Glab and Kulig, 2008), and controls runoff and soil erosion (Bhatt and Khera, 2006).

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 (Anikwe *et al.*, 2007). Plastic mulches directly affect the microclimate around the plant by modifying the radiation budget of the surface and decreasing the soil water loss (Liakatas *et al.*, 1986). The color of plastic mulch largely determines its energy-radiation behaviour and its influence on the microclimate around a plant (Lamont, 1999). Color 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 (Lamont, 1999; Aniekwe *et al.*, 2004).

Soil tillage is one of the very important factors that affect soil physical properties and yield (Keshavarzpour and Rashidi, 2008; Rashidi and Keshavarzpour, 2008). Khurshid *et al.* (2006) 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

(Hammel, 1989), 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 (Lal, 1993). 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 (Iqbal *et al.*, 2005).

Most of the tomato area in Iran is under conventional tillage (Iranian Ministry of Agriculture, Statistical Yearbook, 2006). Conventional tillage practices modify soil structure by changing its physical properties such as soil bulk density, soil penetration resistance and soil moisture content (Keshavarzpour and Rashidi, 2008; Rashidi and Keshavarzpour, 2008). 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 (Rashidi and Keshavarzpour, 2007; Rashidi *et al.*, 2008). 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 (Khan *et al.*, 2001; Khurshid *et al.*, 2006).

On the other hand, conservation tillage methods often result in decreased pore space (Hill, 1990), increased soil strength (Bauder *et al.*, 1981) and stable aggregates (Horne *et al.*, 1992). The pore network in conservationally tilled soil is usually more continuous because of earthworms, root channels and vertical cracks (Cannel, 1985). Therefore, conservation tillage may reduce disruption of continuous pores. Reddy *et al.* (2007) 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 (Iqbal *et al.*, 2005). Conservation tillage and no-tillage methods in arid lands of Iran had an adverse effect on yields of some crops (Hemmat and Taki, 2001). Conversely, while comparing conventional tillage method to conservation tillage and no-tillage methods Chaudhary *et al.* (1992) concluded that higher moisture preservation and 13% more income were obtained in case of no-tillage.

Although considerable amount of research has been done on many crops, information on response of tomato to different farming systems like mulching, conservation tillage and no-tillage methods are meager. 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 including tomato. Therefore, the present investigation was planned to determine the effect of black plastic mulch and different tillage methods on yield and yield components of tomato in the arid lands of Iran.

MATERIALS AND METHODS

Experimental site

The experiment was carried out for two consecutive growing seasons (2007 and 2008) at the Research Site of Tehran Province Agricultural and Natural Resources Research Center in Varamin, Iran. The site is located at latitude of 35° 19' N and longitude of 51° 39' E and is 1000 m above mean sea level, in arid climate in the center of Iran, where the summers are dry and hot while the winters are cool. The soil of the experimental site was a fine, mixed, thermic, Typic Haplocambids sand loam soil. Details of soil physical and chemical properties of the experimental site are given in Table-1.

Table-1. Soil physical and chemical properties of the experimental site (0-30 cm depth).

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
Organic carbon (%)	0.50
Total N (%)	0.06
Available P (ppm)	9.20
Available K (ppm)	272
Available Fe (ppm)	2.82
Available Zn (ppm)	2.06
Available Cu (ppm)	0.90
Available Mn (ppm)	8.20
Available B (ppm)	2.06

Soil sampling and analysis

In order to determine soil physical and chemical properties of the experimental site, a composite soil sample was collected from 18 points in the entire plot before treatment imposition in 2007. 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. Total N (%) was determined by the macro-Kjeldahl method (Bremner, 1982). Available P (ppm) was found using Bray II method according to Olsen (1982). The exchangeable cations were calculated by the method described by Thomas (1982). Soil EC and soil pH values were obtained by using a HI9813-5 portable pH/EC/TDS/°C meter (HANNA instruments, Romania, 2002). Soil organic carbon was determined by Walkley-Black procedure (Nelson and Sommers, 1982). Particle size distribution was determined by hydrometer method (Gee and Bauder, 1986). Dry bulk density was found by the core method (Blake and Hartge, 1986).

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 (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 2007 and 2008 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.

Weather parameters

The mean monthly rainfall and temperature data of the experimental site for 2007 and 2008 are given in Figure-1.

Observation and data collection

Tomatoes were harvested three times (23 July, 12 August and 31 August, respectively) and standard procedures (Srivastava *et al.*, 1994) were adopted for recording the data on yield and yield components. Yield, plant population density (PPD) 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 (Doss *et al.*, 1980; Jain *et al.*, 2000). The TSS of tomatoes was measured using an ATC-1E hand-held refractometer (ATAGO, Japan, 2005) at temperature of 20°C.

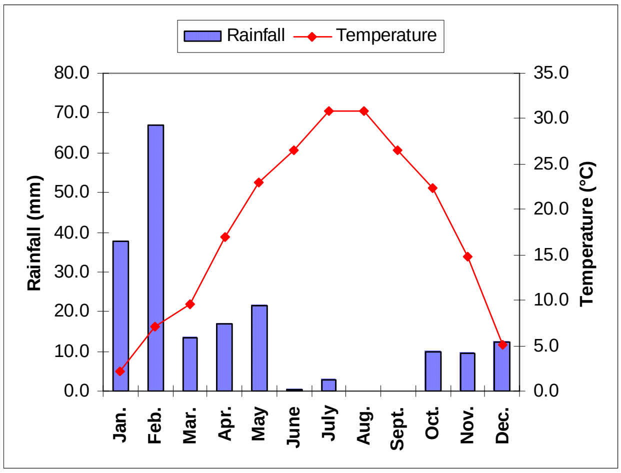

Figure-1. Mean monthly rainfall and temperature during crop growth, 2007 and 2008.

Data analysis

The Data were subjected to ANOVA using statistical software, SPSS 12.0 for Windows (SPSS Inc., 233 S Wacker Drive, Chicago, IL, USA). Means were separated by Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$ (Steel and Torrie, 1984).

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 PPD and NFPP. Significantly higher PPD and NFPP were observed in PM plots (10481 plants ha^{-1} and 17.6, respectively) compared to NM plots (7350 plants ha^{-1} and 14.2, respectively). 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 PPD and NFPP. Significantly higher PPD and NFPP were observed in the CT plots (11438 plants ha^{-1} and 20.4, respectively) compared to MT (9033 plants ha^{-1} and 15.0, respectively) and NT (6275 plants ha^{-1} 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, PPD, 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, PPD 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}), PPD (12850 plants ha^{-1}) and NFPP (21.7) was obtained in case of PM × CT combination, and minimum mean value for yield (3.70 t ha^{-1}), PPD (5117 plants ha^{-1}) and NFPP (10.2) was obtained in case of NM × NT combination. In addition, in both mulch levels yield, PPD 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).

Table-2. Mean squares from the analysis of variance of yield and yield components of tomato under different treatments (mean of 2007 and 2008).

Source of variation	**Degree of freedom**	**Mean square**						
		Yield	**PPD**	**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

* = Significant at 0.05 probability level; ns = Non-significant
(PPD: plant population density; 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 and yield components of tomato for different studied treatments using DMRT at 5% probability (mean of 2007 and 2008).

Treatments		**Yield** (t ha^{-1})	**PPD** (plants ha^{-1})	**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; PPD: plant population density; 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 and yield components of tomato for mulch level and tillage method combinations using DMRT at 5% probability (mean of 2007 and 2008).

Mulch level × tillage method		**Yield** (t ha^{-1})	**PPD** (plants ha^{-1})	**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; PPD: plant population density; NFPP: number of fruits per plant; FW: fruit weight; FL: fruit length; FD: fruit diameter; TSS: total soluble solids)

DISCUSSIONS

In this study, the salient components of yield such as PPD, 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, PPD, 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 PPD (10481 plants ha^{-1}) 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 PPD 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 PPD (7350 plants ha^{-1}) 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 PPD 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 Aniekwe *et al.* (2004) and Anikwe *et al.* (2007) 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.* (2006) and Glab and Kulig (2008) that mulching increased soil porosity and reduced soil compaction. These results are also in agreement with those of Sarkar and Singh (2007), Sarkar *et al.* (2007), Khurshid *et al.* (2006) and Seyfi and Rashidi (2007) 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 PPD (11438 plants ha^{-1}) 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 PPD 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 Khan *et al.* (1999), Khan *et al.* (2001), Iqbal *et al.* (2005), Khurshid *et al.* (2006), Rashidi and Keshavarzpour (2007), Keshavarzpour and Rashidi (2008), Rashidi and Keshavarzpour (2008) and Rashidi *et al.* (2008) 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 PPD (6275 plants ha^{-1}) 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 PPD 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 Bauder *et al.* (1981), Hill (1990) and Horne *et al.* (1992), 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, plant population density and consequently yield. These results are also in line with the results reported by Iqbal *et al.* (2005) 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 Hemmat and Taki (2001), Keshavarzpour and Rashidi (2008), and Rashidi and Keshavarzpour (2008), who concluded that the no-tillage method in arid regions had an adverse effect on yield. As well, Reddy and Reddy (2008) 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.

CONCLUSIONS

The above information suggests that integrated use of mulch and tillage was beneficial in improving the growth and yield of tomato in the arid land of Iran.

ACKNOWLEDGEMENTS

Thanks to Eng. Mohammad-Reza Imani and Eng. Mohsen Seilsepour for statistical expertise on several occasions, and Eng. Fereydoun Keshavarzpour for technical help and instrumentation. The financial support provided by the Agricultural Research, Education and Extension Organization of Iran under research award number 2-109-220000-14-0000-86008 is gratefully acknowledged.

REFERENCES

Aniekwe N.L., Okereke O.U. and Anikwe M.A.N. 2004. Modulating effect of black plastic mulch on the environment, growth and yield of cassava in a derived savannah belt of Nigeria. Tropicultura. 22: 185-190.

Anikwe M.A.N., Mbah C.N. Ezeaku P.I. and Onyia V.N. 2007. Tillage and plastic mulch effects on soil properties and growth and yield of cocoyam (*Colocasia esculenta*) on an ultisol in southeastern Nigeria. Soil and Tillage Res. 93: 264-272.

Bauder J.W., Randall G.W. and Swan J.B. 1981. Effects of four continue tillage systems on mechanical impedance of a clay-loam soil. Soil Sci. Soc. Amer. J. 45: 802-806.

Bhatt R. and Khera K.L. 2006. Effect of tillage and mode of straw mulch application on soil erosion in the sub-mountainous tract of Punjab, India. Soil and Tillage Res. 88: 107-115.

Blake G.R. and Hartge K.H. 1986. Bulk density. In: Klute A. (Ed.). Methods of Soil Analysis. Part-1, 2nd Ed., Agronomy Monograph No. 9. ASA and SSSA, Madison, WI. pp. 365-375.

Bremner J.M. 1982. Total nitrogen. In: Page A.L. Miller R.H. and Keeny D.R. (Eds.). Methods of Soil Analysis. Part-2, 2nd Ed. Agronomy Monograph No. 9. ASA and SSSA, Madison, WI. pp. 915-928.

Cannel R.Q. 1985. Reduced tillage in north-west Europe - A review. Soil and Tillage Res. 5: 129-177.

Chaudhary A.D., Javed M. Rana, M.A. Sarwar and Zaman Q. 1992. Comparative performance of direct drilling and conventional tillage practices under rice-wheat rotation system. Pakistan J. Agric. Sci. 29: 5-8.

Doss B.D., Turner J.L. and Evans L.E. 1980. Irrigation methods and in row chiseling for tomato production. J. Am. Soc. Hortic. Sci. 105: 611-614.

Gee G.W. and Bauder J.W. 1986. Particle size analysis. In: Klute A. (Ed.). Methods of Soil Analysis. Part-1, 2nd Ed. Agronomy Monograph No. 9. ASA and SSSA, Madison, WI. pp. 383-411.

Glab T. and Kulig B. 2008. Effect of mulch and tillage system on soil porosity under wheat (*Triticum aestivum*). Soil and Tillage Res. 99: 169-178.

Hammel J.E. 1989. Long term tillage and crop rotation effects on bulk density and soil impedance in northern Idaho. Soil Sci. Soc. Amer. J. 53: 1515-1519.

Hemmat A. and Taki D. 2001. Grain yield of irrigated wheat as affected by stubble tillage management and seeding rates in central Iran. Soil and Tillage Res. 63: 57-64.

Hill R.L. 1990. Long-term conventional and no-tillage effects on selected soil physical properties. Soil Sci. Soc. Amer. J. 54: 161-166.

Horne D.J., Ross C.W. and Hughes K.A. 1992. Ten years of maize/oats rotation under three tillage systems on a silt-loam soil in New Zealand- A comparison of some soil properties. Soil and Tillage Res. 22: 131-143.

Iqbal M., Hassan A.U., Ali A. and Rizwanullah M. 2005. Residual effect of tillage and farm manure on some soil physical properties and growth of wheat (*Triticum aestivum* L.). Int. J. Agri. Biol. 7: 54-57.

Jain N., Chauhan H.S., Singh P.K. and Shukla K.N. 2000. Response of tomato under drip irrigation and plastic mulching. In: Proceedings of 6th International Micro-irrigation Congress, Micro-irrigation Technology for developing Agriculture. 22-27 October 2000. South Africa.

Keshavarzpour F. and Rashidi M. 2008. Effect of different tillage methods on soil physical properties and crop yield of watermelon (*Citrullus vulgaris*). World Appl. Sci. J. 3: 359-364.

Khan F.U.H., Tahir A.R. and Yule I.J. 1999. Impact of different tillage practices and temporal factor on soil moisture content and soil bulk density. Int. J. Agri. Biol. 1: 163-166.

Khan F.U.H., Tahir A.R. and Yule I.J. 2001. Intrinsic implication of different tillage practices on soil penetration resistance and crop growth. Int. J. Agri. Biol. 3: 23-26.

Khurshid K., Iqbal M., Arif M.S. and Nawaz A. 2006. Effect of tillage and mulch on soil physical properties and growth of maize. Int. J. Agri. Biol. 8: 593-596.

Lal R. 1993. Tillage effects on soil degradation, soil resilience, soil quality and sustainability. Soil and Tillage Res. 51: 61-70.

Lamont W.J. 1999. Vegetable production using plasticulture. Food and Fertilizer Center. Extension Bulletin 476, No. 10.

Liakatas A.J., Clark A. and Monteita J.L. 1986. Measurements of the heat balance under plastic mulches. Part-1. Radiation balance and soil heat flux. Agric. Meteorol. 36: 227-239.

Nelson D.W. and Sommers L.E. 1982. Total carbon, organic carbon and organic matter. In: Page A.L. Miller R.H. and Keeny D.R. (Eds.). Methods of Soil Analysis. Part-2, 2nd Ed. Agronomy Monograph No. 9. ASA and SSSA, Madison, WI. pp. 539-579.

Olsen S.R. 1982. Phosphorus. In: Page A.L. Miller R.H. and Keeny D.R. (Eds.). Methods of Soil Analysis. Part-2, 2nd Ed. Agronomy Monograph No. 9. ASA and SSSA, Madison, WI. pp. 403-430.

Rashidi M. and Keshavarzpour F. 2007. Effect of different tillage methods on grain yield and yield components of maize (*Zea mays* L.). Int. J. Agri. Biol. 9: 274-277.

Rashidi M. and Keshavarzpour F. 2008. Effect of different tillage methods on soil physical properties and crop yield of melon (*Cucumis melo*). American-Eurasian J. Agric. and Environ. Sci. 3: 31-36.

Rashidi M., Keshavarzpour F. and Gholami M. 2008. Effect of different tillage methods on yield and yield components of forage corn. American-Eurasian J. Agric. and Environ. Sci. 3: 347-351.

Reddy S.S., Reddy K.C. and Tiffany R. 2007. Influence of tillage and poultry litter application on carbon dioxide efflux and carbon storage in soil under cotton production system. Proceedings of ASA-CSSA-SSSA International meetings, New Orleans, LA, Nov 4-8, 2007. Available at http://a-c-s.confex.com/a-c-s/2007am/techprogram/P34934.htm.

Reddy S. S. and Reddy K.C. 2008. Cotton lint yield and soil quality as influenced by continuous poultry litter application for 5-yr. Proceedings of ASA-CSSA-SSSA. International meetings, Houston, TX, Oct. 5-9, 2008. Available at http://a-c-s.confex.com/crops/2008am/techprogram/P43784.htm.

Sarkar S. and Singh S.R. 2007. Interactive effect of tillage depth and mulch on soil temperature, productivity and water use pattern of rainfed barley (*Hordium vulgare* L.). Soil and Tillage Res. 92: 79-86.

Sarkar S., Paramanick M. and Goswami S.B. 2007. Soil temperature, water use and yield of yellow sarson (*Brassica napus* L. var. glauca) in relation to tillage intensity and mulch management under rainfed lowland ecosystem in eastern India. Soil and Tillage Res. 93: 94-101.

Seyfi K. and Rashidi M. 2007. Effect of drip irrigation and plastic mulch on crop yield and yield components of cantaloupe. Int. J. Agri. Biol. 9: 247-249.

Srivastava P.K., Parikh M.M., Sawani N.G. and Raman S. 1994. Effect of drip irrigation and mulching on tomato yield. Water Management. 25: 179-184.

Steel R.G.D. and Torrie J.H. 1984. Principles and Procedures of Statistics: A Biometrical Approach. McGraw Hill Book Co., Inc., New York, USA.

Thomas G.W. 1982. Exchangeable cations. In: Page A.L. Miller R.H. and Keeny D.R. (Eds.). Methods of Soil Analysis. Part-2, 2nd Ed. Agronomy Monograph No. 9. ASA and SSSA, Madison, WI. pp. 159-165.

Zaman W.U., Arshad M. and Saleem A. 2001. Distribution of nitrate-nitrogen in the soil profile under different irrigation methods. Int. J. Agri. Biol. 3: 208-209.