RESPONSE OF CROP YIELD AND YIELD COMPONENTS OF TOMATO TO DIFFERENT TILLAGE METHODS IN THE ARID LANDS OF VARAMIN, IRAN

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ABSTRACT

A field experiment was conducted at the Research Site of Varamin Agricultural Research Center, Varamin, Iran on sandy loam soils to study the response of tomato (*Lycopersicon esculentum*) to different tillage methods during 2007 and 2008. Tillage treatments in the study included were conventional tillage (CT; moldboard plowing + two passes of disk harrowing), minimum tillage (MT; one pass of disk harrowing) and no-tillage (NT). Crop yield, yield components (plant population density, PPD; number of fruits per plant, NFPP; fruit weight, FW; fruit length, FL; fruit diameter, FD) and a fruit quality parameter (total soluble solids, TSS) were determined for all treatments. Results indicated that tillage methods significantly ($P \leq 0.05$) influenced crop yield, yield components and TSS. Results also showed that PPD and NFPP are the most important yield components explaining crop yield difference under different tillage methods. The maximum PPD (10025 plants ha^{-1}), NFPP (19.1) and as a result crop yield (12.2 t ha^{-1}) were observed with CT, while maximum values of FW (71.2 g), FL (70.0 mm), FD (59.2 mm) and TSS (7.27%) were noted NT plots. On the other hand, minimum PPD (5117 plants ha^{-1}), NFPP (10.2) and hence crop yield (3.70 t ha^{-1}) were obtained with NT, while the minimum values of FW (63.6 g), FL (61.0 mm), FD (53.6 mm) and TSS (5.81%) were noted in case of CT treatment. Therefore, one pass of moldboard plow followed by two passes of disk harrow was found to be more appropriate and profitable tillage method in improving crop yield of tomato in the arid lands of Iran.

Key words: Conventional tillage; Conservation tillage; Minimum tillage; No-tillage; Tomato (*Lycopersicon esculentum*); Crop yield; Arid lands; Varamin; Iran

Running title: RESPONSE OF TOMATO TO TILLAGE METHODS

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. 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 (Iranian Ministry of Agriculture, Statistical Yearbook, 2006).

Soil tillage is one of the very important factors that affect soil physical properties and crop yield (Keshavarzpour & Rashidi, 2008; Rashidi & 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 often 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 & Rashidi, 2008; Rashidi & 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 & Keshavarzpour, 2007; Rashidi *et al.*, 2008). This difference results change in 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 continues because of earthworms, root channels and vertical cracks (Cannel, 1985). Therefore, conservation tillage may reduce disruption of continues 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 & 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.
Though considerable amount of research has been done on many crops, information on response of tomato to conservation tillage and no-tillage methods is meager. At this time, a wide range of tillage methods is being used in Iran without evaluating their effects on crop yield and yield components of tomato. Therefore, the present investigation was planned to determine the response of crop yield and yield components of tomato to different tillage methods 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 Varamin Agricultural Research Center, 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.

Weather parameters: The mean monthly rainfall and temperature data of the experimental site for 2007 and 2008 are given in Fig. 1.

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 (2002, HANNA instruments, Romania). Soil organic carbon was determined by Walkley-Black procedure (Nelson & Sommers, 1982). Particle size distribution was determined by hydrometer method (Gee & Bauder, 1986). Dry bulk density was found by the core method (Blake & Hartge, 1986).

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

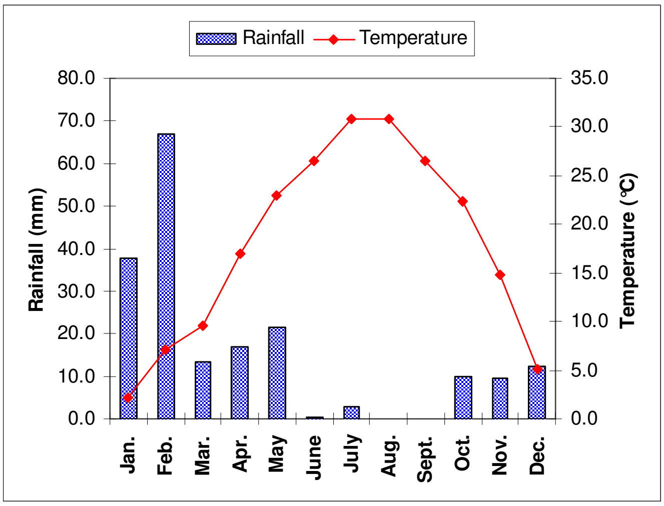

Fig. 1: Mean monthly rainfall and temperature during crop growth, 2007 and 2008

Field methods: The experiments were laid out in a randomized complete block design (RCBD). Tillage treatments included conventional tillage (CT), minimum tillage (MT) and no-tillage (NT) and they were replicated thrice. Conventional tillage included one pass of moldboard plow to a depth of 15 cm and was followed by two passes of disk harrowing. Minimum tillage included only one pass of disk harrowing. No-tillage included 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 the both sides of each furrow with 50 cm plant to plant spacing (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 5^{th} May when the soil was well irrigated in all treatments. 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) and standard procedures were adopted for recording the data on crop yield and yield components. Crop 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 (Srivastava *et al.*, 1994). 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 (2005, ATAGO, Japan) at temperature of 20°C.

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 & Torrie, 1984).

RESULTS

Crop yield and yield components of tomato were significantly influenced by tillage methods. Among three different tillage methods CT method recorded significantly higher crop yield (12.2 t ha^{-1}) compared to NT (3.7 t ha^{-1}) and MT (6.2 t ha^{-1}) methods. Between two conservation tillage methods MT method recorded significantly higher crop yield (67%) than NT method. Similar trend was also observed in case of PPD and NFPP. Significantly higher PPD and NFPP were observed in CT plots (10025 plants ha^{-1} and 19.1, respectively) compared to MT (6908 plants ha^{-1} and 13.2, respectively) and NT (5117 plants ha^{-1} and 10.2, respectively) plots (Table 2).
In contradiction to above trend, NT and MT methods recorded significantly higher FW, FL, FD and TSS compared to CT method. Between conservation tillage methods, NT method recorded higher values for the above parameters. Values of FW, FL and FD were 12, 15 and 10%, respectively higher in NT plots compared to that of CT plots. The quality parameter of tomato fruits, TSS was significantly higher in NT plots (7.27%) compared to that of CT (5.81%) and MT (6.31%) plots (Table 2).

Table 2. Effect of different tillage treatments on crop yield and yield components of tomato (mean 2007 and 2008).

Treatments	Crop yield	PPD (plant ha⁻	NFPP	FW (g)	FL (mm)	FD (mm)	TSS (%)
Conventional tillage	12.2 a	10025 a	19.1 a	63.6 c	61.0 c	53.6 c	5.81 c
Minimum tillage (MT)	6.19 b	6908 b	13.2 b	67.6 b	64.8 b	57.6 b	6.31 b
No-tillage (NT)	3.70 c	5117 c	10.2 c	71.2 a	70.0 a	59.2 a	7.27 a
$LSD_{5\%}$	0.160	244.9	0.373	0.742	1.260	0.991	0.453

Means in the same column with different letters differ significantly at 0.05 probability level according to DMRT
(PPD: plant population density, NFPP: number of fruits per plant, FW: fruit weight, FL: fruit length, FD: fruit diameter, TSS: total soluble solids)

DISCUSSION

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

The maximum value of PPD (10025 plants ha^{-1}) and NFPP (19.1) was observed in case of CT treatment, while maximum value of FW (71.2 g), FL (70.0 mm), FD (59.2 mm) and TSS (7.27%) was noted in case of NT treatment. As PPD and NFPP were the most important yield components explaining crop yield of tomato under different tillage methods, the maximum value of crop yield (12.2 t ha^{-1}) was observed in case of CT treatment (Table 2). 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 & Keshavarzpour (2007), Keshavarzpour & Rashidi (2008), Rashidi & 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 suppressing weed growth which favorably affect root development, plant growth, plant population density and as a result crop yield.

On the other hand, the minimum value of PPD (5117 plants ha^{-1}) and NFPP (10.2) was obtained in case of NT treatment, while the minimum value of FW (63.6 g), FL (61.0 mm), FD (53.6 mm) and TSS (5.81%) was noted in case of CT treatment. In view of the fact that PPD and NFPP were the most important yield components explaining crop yield of tomato under different tillage methods, the minimum value of crop yield (3.70 t ha^{-1}) was obtained in case of NT treatment (Table 2). These results are in agreement with those of Bauder *et al.* (1981), Hill (1990), 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 crop 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 & Taki (2001), Keshavarzpour & Rashidi (2008) and Rashidi & Keshavarzpour (2008), who concluded that no-tillage method in arid regions had an adverse effect on crop yield. Furthermore, Reddy and Reddy (2008) opinioned 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

Above information suggests that among three methods of tillage imposed, conventional tillage (CT) method was found to be better over the minimum tillage (MT) and no-tillage (NT) methods in achieving higher crop yield of tomato through improving plant population density (PPD) and number of fruits per plant (NFPP). Reduced soil penetration resistance, reduced soil bulk density, increased soil moisture preservation, enhanced root-soil contact and better suppressing weed growth might have helped in retaining good PPD and NFPP, and in turn higher crop yield in conventionally tilled plots. It can be concluded that one pass of moldboard plow followed by two passes of disk harrow can be recommended as more appropriate and profitable tillage method in improving crop yield of tomato in the arid lands of Iran. Further long-term studies are needed to find the beneficial effects of no-tillage on soil quality and crop yields when it was supplemented with extra nutrients or crop residue.

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