**INTERMEDIATE EFFECTS OF RESIDUE AND TILLAGE METHODS ON GROWTH, YIELD AND YIELD COMPONENTS OF MELON**

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**ABSTRACT**

Field experiments were conducted to investigate the effects of residue and tillage on growth and yield of melon. Tillage treatments included conventional tillage (using a moldboard plough and two passes with a disk harrow), minimum tillage (one pass with a disk harrow), and no tillage (NT). Residue treatments included the application of 0%, 30% and 60% residue. Yield and yield components were obtained for all treatments. Tillage significantly affected yield and its components (P ≤ 0.05). The maximum FWPP (2.678 kg), NFPP (6.799), D (18.49 cm), L (45.93 cm), S (12.51%) and RUE (2.470) and yield (16.17 t/ha) were recorded in the conventional tillage treatment. Also, maximum FWPP (2.192 kg), NFPP (5.353), D (16.66 cm), L (39.52 cm) and yield (12.83 t/ha) were observed in the 30% residue treatment. In terms of the interaction effects, maximum FWPP (2.850 kg), NFPP (6.790), D (20.71 cm), L (53.53 cm) and yield (17.09 t/ha) were obtained in the conventional tillage + 30% residue treatment. Therefore, the use of a moldboard plough followed by two passes with a disk harrow, in concert with 30% residue treatment, were maximizing the yield. Almost all growth indicators had the optimum values in the conservation tillage treatments.

**INTRODUCTION**

Tillage fundamentally affects soil properties and crop yield (Li, Li, Cui, Jagadamma, & Zhang, 2019). Kurshid, Iqbal, Arif, & Nawaz (2006) stated that tillage can determine up to 20% of crop production. The method used for soil tillage can determine the sustainability of agricultural activities through its effects on soil properties (Hill, 1990). Inappropriate tillage can negatively impact soil by damaging soil structure, increasing erosion, promoting the loss of organic matter and nutrients, and interfering with the natural carbon and water cycles in the soil (Kassam, Friedrich, Derpsch, & Kienzle, 2015). Therefore, researchers have begun to study alternative methods of tillage, such as conservation tillage and no-tillage methods (Iqbal, Anwar-ul-Hassan, Ali, & Rizwanullah, 2005). Conventional tillage changes soil structure and affects many properties of soil such as moisture content and bulk density (Upadhyay & Raheman, 2018). Repeated tillage breaks up soil aggregates, creating a fine soil with little structure, while conservation tillage and no-tillage methods preserve the natural structure of the soil (Rashidi, Keshafarzpour, & Gholami, 2008; Rashidi & Keshavarzpour, 2007a). Soil structure is partly responsible for the configuration of the pore network in the soil, which in turn determines the permeability of soil to air, water, and agricultural chemicals, as well as the ability of soil to store water. Together, these factors can create a suitable environment for the growth of crops (Akbari et al., 2019; Kurshid, Iqbal, Arif, & Nawaz, 2006; Nabati et al., 2020).
Melon (Cucumis melo L.) is the third most widely cultivated vegetable crop in Iran (after tomato and watermelon) and has adapted to the country’s soil and climatic conditions over the years. In the past two years, an average of 1.5 million tons of melon have been produced in Iran (Statistical Center of Iran, 2016). In the majority of lands under melon cultivation in Iran, conventional tillage practices are used (Statistical Center of Iran, 2015). However, meeting the increasing demand for food crops calls for the adoption of new crop management systems such as conservation agriculture (Laborde, Wortmann, Blanco-Canqui, Baigorria, & Lindquist, 2020). Although conservation tillage methods often reduce the pore space in the soil (Hill, 1990), these spaces are more stable due to the preservation of earthworms, root canals, and small cracks; conservation agriculture also promotes soil strength and improves the stability of aggregates (Awe, Reichert, & Fontanela, 2020; Peixoto et al., 2019). Conservation tillage also improves carbon sequestration in the soil, as indicated by reduced CO₂ emission from soil (Nasr ian et al., 2019; Reddy, Reddy, & Roberson, 2007).

However, different results have been reported for the impact of conservation agriculture on crop yield (Iqbal, Anwar-ul-Hassan, Ali, & Rizwanullah, 2005). Past studies have shown that these practices reduce yield in arid environments such as Iran (Hemmat & Taki, 2001). On the other hand, Chaudhry, Javed, Rana, & Sarwar (1992) stated that conservation tillage and no tillage improve soil moisture content and farmers’ income. Currently, a wide range of tillage methods are in use in Iran, but little attention has been paid to how they impact crop yield and its components. As a result, this study examines the effects of different tillage methods and residue treatments on the growth, yield, and yield components of melon in Iran.

MATERIALS AND METHODS

Study Site

The study was conducted during the 2017-2019 growing seasons at an experimental station in northeastern Iran. The station is located at 36° 34’ 24” N and 59° 08’ 59” E, 1255 m above sea level. Monthly mean temperature at the station ranges from 8 to 24°C. Total annual rainfall at the site is 130-210 mm/year. Soils in the study area are mainly loamy, and the study site has sandy loam surface soil. Fig. 1 shows mean monthly temperature and rainfall during the study. The experiment was conducted at Khorasan Razavi Agricultural and Natural Resources Research Center in Mashhad, Khorasan Razavi, Iran. The site is located in a temperate cold climatic zone with hot dry summers and cold winters.

Field Experimental Design

The experiments were carried out using a randomized complete block design (RCBD) with three replications. Tillage treatments included conventional tillage (CT, one 15-cm deep pass with a moldboard plough and two passes with a disk harrow), minimum tillage (MT, one pass with a disk harrow) and no-tillage (NT). Residue treatments included 0%, 30% and 60% residue. Each subplot was 80 m long and 13.5 m wide, so the main plots had an area of 3240 m² (3 × 80 × 13.5). Each plots had four rows. Khatoni melon variety, which is a widely cultivated melon variety in Iran, was used in this study. Seeds were planted by hand on both sides of furrows so that there would be a distance of 25 cm between plants. The fertilizers applied were: N (350 kg/ha, as urea), P (100 kg/ha, as triple super phosphate) and K (50 kg/ha, sulphate of potassium). 3 l/ha of glyphosate was used before cultivation for weed control. Seeds were planted on May 6th after irrigation. Pesticides were used according to recommended practices for the local conditions. All interventions were kept uniform across treatments, expect for tillage and residue treatment.

Data Collection and Measurements

Melons were harvested on 13th of July, 2nd of August, and 23rd of August. Yield, yield components, and growth indicators were recorded according to standard practices. Yield, fruit weight per plant (FWPP), number of fruits per plant (NFPP), diameter (D), length (L), sugar content (S), radiation use efficiency (RUE), and water use efficiency (WUE) were measured based on the plants and fruit harvested from the two middle rows in the plots (Doss, Turner, & Evans, 1980; Jain, Chauhan, Singh, & Shukla, 2000; Shrivastava, Parikh, Sawani, & Raman, 1994). Growth indicators were determined five times during the growth period based on the 3rd sample taken randomly from subplots. Total dry weight (TDW) and leaf dry weight (LDW) were measured after drying in an oven, and leaf area index (LAI) was measured using a LAI meter (LI-COR 2000). We also calculated net assimilation rate (NAR), relative growth rate (RGR), crop growth
rate (CGR), specific leaf area (SLA), specific leaf weight (SLW), leaf area ratio (LAR), and leaf area duration (LAD).

Calculating Growth Indices

Plots were sampled every 15 days. To eliminate the effect of margins, four plants were randomly selected from the two middle rows in each plot. Leaf area was measured with a leaf area meter (LI-COR 2000). The samples were dried in an oven for two days at 70 degrees Celsius, and dry weight was then measured. SAS and MSTATC were used to create regression models that best described the changes in LAI, LDW and TDW as a function of days after planting. First the log of measured data was calculated to minimize dependence of variance on the mean, and then the best model was selected according to the coefficient of determination ($R^2$). Table 1 shows the equations used to calculate crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), leaf area duration (LAD), leaf area rate (LAR), Specific leaf weight (SLW) and specific leaf area (SLA). Growth curves were plotted in Excel.

![Fig. 1. Mean monthly temperature (a), total monthly precipitation (b)](image-url)
Data Analysis

Data were analyzed using ANOVA in SPSS 12.0. Duncan’s multiple range test (DMRT) at P ≤ 0.05 was used to test for pair-wise significant differences (Steel & Torrie, 1984).

RESULTS AND DISCUSSION

Growth Degree Day (GDD)

Growth degree day (GDD) is the cumulative measure of temperatures in which a plant is exposed beyond a baseline temperature (Tb). GDD is used by horticulturalists to predict phenological events such as flowering or fruit ripening. GDD for each day is calculated as an average daily temperature minus the baseline temperature (Neamatollahi, Bannayan, Jahansuz, Struik, & Farid, 2012). This index is used to evaluate the suitability of a region for different crops, monitor the growth and development of crops and pests, determine optimal timing for application of fertilizers and pesticides, and plan planting days to stagger crop harvest. Melon needs 1790 cumulative degrees temperature from emergence to harvest (Fig. 1), corresponding to 121 days after planting seeds in our study area (Fig. 2). In addition, the use of GDD can be used to measure the heat requirements associated with the phenological stages of the crop (León et al., 2019), predict and set up the schedule of herbicide application, fertilizer application, irrigation, and pest management (León Pacheco et al., 2019; Villordon, Clark, Ferrin, & LaBonte, 2009).

Table 1. Calculation of indices

| Parameters                  | Equations                                                      | Unit   |
|-----------------------------|----------------------------------------------------------------|--------|
| Total dry weight (TDW)      | \( \text{Exp}(a_1t+b_1t+c_1t^{0.5}+d_1t^2+e_1t^3) \)          | g/m²   |
| Leaf dry weight (LDW)       | \( \text{Exp}(a_3t+b_3t+c_3t^{0.5}+d_3t^2+e_3t^3) \)          | g/m²   |
| Leaf area index (LAI)       | \( \text{Exp}(a_2+b_2t+c_2t^{0.5}+d_2t^2+e_2t^3) \)          |        |
| Crop growth rate (CGR)      | \( (b_1+0.5c_1t^{0.5}+2d_1t+3e_1t^2) \times (TDW) \)         | g/m².day|
| Relative growth rate (RGR)  | \( (b_1+0.5c_1t^{0.5}+2d_1t+3e_1t^2) \)                       | g/g.day |
| Net assimilation rate (NAR) | \( \frac{\text{CGR}}{\text{LAI}} \)                         | g/m².day|
| Leaf area rate (LAR)        | \( \frac{\text{LAI}}{\text{TDW}} \)                         | m²/g   |
| Leaf area duration (LAD)    | \( \frac{(\text{LAI}_1+\text{LAI}_2)/2 \times (T_2-T_1)}{2} \) |        |
| Specific leaf area (SLA)    | \( \frac{\text{LAI}}{\text{LDW}} \)                         | m²/g   |
| Specific leaf weight (SLW)  | \( \frac{1}{\text{SLA}} \)                                   | m²/g   |

Growth Indicators

Total dry weight (TDW), leaf dry weight (LDW), and leaf area index (LAI) were observed as plant growth indicators. The best treatment in terms of TDW was conventional tillage with 30% residue treatment, followed by conventional tillage with 0% and 60% residue (Fig. 3). It is related to the report by Mathew et al. (2012) that conservation tillage practices improve the physicochemical and microbiological properties of soil. Both aspects of soil can stimulate the growth and development of crops.

Leaf Area Index as the total area of leaves per unit area of land, is used to characterize plant canopies. The best treatment in terms of LAI was conventional tillage with 30% residue (Fig. 3). The best treatments with respect to net assimilation rate were conventional tillage with 60% and 30% residue (Fig. 4).

The best treatment in terms of crop growth rate was conventional tillage with 30% residue (Fig. 5). Plant Growth Rate (PGR) captures how fast a plant grows and is measured as the daily increase in mass divided by the aboveground biomass of the plant (Fig. 5).

Specific leaf area is calculated by dividing leaf area by dry mass. SLA is commonly used to study leaf traits (Kraft, Valencia, & Ackerly, 2008). The best treatment with respect to specific leaf area was minimum tillage with 30% residue (Fig. 6). The treatment using conventional tillage with 30% residue had the highest SLW (Fig. 6).
Fig. 2. Melon morphological changes based on GDD (left) and Relation between GDD with days after sowing in melon (right).

Fig. 3. Melon total dry weight (TDW)

Fig. 4. Changes in leaf area index (LAI) (left) and net assimilation rate (NAR) (right) in different treatments.
Fig. 5. Changes in relative growth rate (RGR) (left) and crop growth rate (CGR) (right) in different treatments.

Fig. 6. Changes in specific leaf area (SLA) (left) and specific leaf weight (SLW) (right) in different treatments.
Effects of Residue and Tillage Methods on Melon

Yield and Yield Components

Tillage practices significantly impacted yield and yield components. Conventional tillage resulted in the highest yield (16.17 t/ha), followed by minimum tillage (11.60 t/ha) and no tillage (7.80 t/ha). FWPP, NFPP, D, L, S, and RUE followed the same trend, with conventional tillage resulting in the highest values. Significantly higher FWPP, NFPP, D, L, S, and RUE were observed in the conventional tillage plots (2.678, 6.799, 18.49, 45.93, 12.51 and 2.47, respectively) compared to minimum tillage (1.934, 4.421, 14.6, 34.33, 9.954 and 1.072, respectively) and NT (1.320, 3.660, 13.41, 31.71, 10.75 and 0.2344, respectively) plots (Fig. 7 and Table 2).

Residue treatments also significantly affected yield and its components. Among the residue treatments, the 30% treatment showed significantly higher yield (12.83 t/ha) compared to 0% (11.53 t/ha) and 60% (11.21 t/ha) treatments. FWPP was significantly higher in the 30% plots (2.192) compared to 0% and 60% plots (1.898 and 1.842, respectively). NFPP, D, and L followed a similar trend with 30% residue treatments producing significantly higher values compared to 0% and 60% treatments. The interaction effects of tillage method and residue treatment also influenced yield and yield components. Among the nine different tillage*residue treatments, the CT30% and CT60% treatments recorded significantly higher yield (17.09 and 16.06 t/ha, respectively). Significantly higher NFPC was observed in all CT plots. Significantly higher FWPP was observed in the CT30% plot (2.850) (Fig. 8 and Table 3).

We investigated FWPP, NFPP, D, L, S, RUE and WUE under different tillage and residue treatments and examined how conservation agriculture practices impact the yield and yield components of melon. The results show that tillage method and residue treatment significantly affected the observed parameters. The maximum value of FWPP (2.850), NFPP (6.820), D (20.71), L (53.53), S (12.94), RUE (3.940), and yield (17.09 t/ha) were observed in CT treatments (Table 3). Overall, the CT30% treatment seems to be the best combination of treatments since it had maximum yield, FWPP, NFPP, D, and L.

Our results are in line with Iqbal, Anwar-ul-Hassan, Ali, & Rizwanullah (2005), Khan, Tahir, & Yule (2001), Kurshid, Iqbal, Arif, & Nawaz (2006), Rashidi, Keshafarzpour, & Gholami (2008), Rashidi & Keshavarzpour (2008), and Rashidi & Keshavarzpour (2007a); (2007b). These studies reported that conventional tillage reduces the penetration resistance of soil, lowers bulk density, improves moisture retention, and suppresses weed growth. Conventional tillage also produces better outcomes in terms of root development, plant growth, and crop yield. The lowest value of yield (6.687 t ha⁻¹) was obtained in the NT60% treatment (Table 3). Bauder, Randall, & Swann (1981), Hill (1990) and Hughes, Horne, Ross, & Julian (1992) also reported that conservation tillage can restrict pore space, decrease permeability, bulk density, and moisture retention, as well negatively impacting plant growth, plant development and crop yield. Iqbal, Anwar-ul-Hassan, Ali, & Rizwanullah (2005) stated that no-tillage methods are unable to overcome initial poor conditions of soil such as poor texture and low organic matter content. Hemmat & Taki (2001), Rashidi & Keshafarzpour (2008), and Rashidi & Keshavarzpour (2007b) also reported that no-tillage methods lower crop yield in arid regions such as our study area.

Table 2. Mean squares from ANOVA for yield, yield components and quality parameter

| S.O.V     | df | Yield  | Fruit weight | Number fruit | Diameter | Length | Sugar | RUE  | WUE  |
|-----------|----|--------|--------------|--------------|----------|--------|-------|------|------|
| Tillage   | 2  | 157.754** | 4.160**      | 24.129**     | 63.454** | 515.820** | 15.322** | 10.280* | 7.134** |
| Residues  | 2  | 6.654**  | 0.318**      | 1.265**      | 9.651**  | 32.634** | 0.714** | 1.156** | 1.678** |
| Tillage*Residues | 4  | 1.299ns  | 0.096**      | 0.713ns      | 3.383**  | 75.588** | 1.105** | 3.111** | 3.300** |
| Error     | 12 | 0.476   | 0.008        | 0.139        | 0.507    | 0.685   | 0.060  | 0.720  | 1.420  |
| CV%       |    | 5.82    | 4.56         | 7.52         | 4.59     | 2.22    | 2.20   | 14.32  | 10.15  |

Remarks: *: significant at 5% level, **: significant at 1% level, ns: non-significant; SOV: Source of Variance, RUE: Radiation use efficiency, WUE: Water use efficiency
Fig. 7. Yield, fruit weight per plant (FWPP), number of flower per plant (NFPP), and radiation use efficiency (RUE) in different tillage treatments.
Fig. 7 (Continue). Yield, fruit weight per plant (FWPP), number of flower per plant (NFPP), and radiation use efficiency (RUE) in different tillage treatments.
Fig. 8. Number of flower per cluster (NFPC), fruit weight per plant (FWPP) and yield; a, b, and c are significantly different at the 5% level according to DMRT.
Table 3. Effect of different tillage treatments on yield and yield components of melon.

| Treat                  | Yield (t/ha) | FWPP (kg) | NFPP | D   | L   | S   | RUE       | WUE       |
|------------------------|--------------|-----------|------|-----|-----|-----|-----------|-----------|
| Tillage                |              |           |      |     |     |     |           |           |
| No till.               | 7.808c       | 1.320c    | 3.660c | 13.41b | 10.75b | 0.2344b | 3.901a    |
| Minimum                | 11.60b       | 1.934b    | 4.421b | 14.60b | 34.33b | 9.954c  | 1.072ab   | 5.682a    |
| Conventional           | 16.17a       | 2.678a    | 6.799a | 18.49a | 45.93a | 12.51a  | 2.470a    | 5.368a    |
| Residue                |              |           |      |     |     |     |           |           |
| 0%                     | 11.53b       | 1.899b    | 4.920ab | 15.18b | 36.08b | 11.40a  | 0.9433a   | 5.160a    |
| 30%                    | 12.83a       | 2.192a    | 5.353a | 16.66a | 39.52a | 10.91b  | 1.192a    | 4.551a    |
| 60%                    | 11.21b       | 1.842b    | 4.607b | 14.66b | 36.38b | 10.91b  | 1.641a    | 5.240a    |
| Tillage × Residue      |              |           |      |     |     |     |           |           |
| No till. × 0%          | 8.277e       | 1.433f    | 4.007c | 14.14d | 32.68fg | 11.56b  | 0.2600a   | 4.577a    |
| No till. × 30%         | 8.460e       | 1.410f    | 4.007c | 13.44de | 28.52h | 10.53c  | 0.3200a   | 3.590a    |
| No till. × 60%         | 6.687f       | 1.117g    | 2.967d | 12.66e | 33.92ef | 10.18cd | 0.1233a   | 3.537a    |
| Minimum × 0%           | 10.95d       | 1.753e    | 3.933c | 14.24d | 35.12de | 9.690e  | 0.7433a   | 4.757a    |
| Minimum × 30%          | 12.95c       | 2.317d    | 5.263b | 15.84c | 36.50d | 10.35c  | 1.613a    | 4.627a    |
| Minimum × 60%          | 10.89d       | 1.733e    | 4.067c | 13.74de | 31.37g | 9.820de | 0.8600a   | 7.663a    |
| Conventional × 0%      | 15.36b       | 2.507c    | 6.820a | 17.17b | 40.43c | 12.94a  | 1.827a    | 6.147a    |
| Conventional × 30%     | 17.09a       | 2.850a    | 6.790a | 20.71a | 53.53a | 11.85b  | 1.643a    | 5.437a    |
| Conventional × 60%     | 16.06ab      | 2.677b    | 6.787a | 17.59b | 43.84b | 12.73a  | 3.940a    | 4.520a    |
| LSD value              | 1.227        | 0.1591    | 0.6633 | 1.267 | 1.472 | 0.4358 | 1.669     | 3.293     |

Remarks: Means in the same column with different letters differ significantly at 5% level according to DMRT; FWPP: fruit weight per plant, NFPP: number of fruit per plant, D: diameter, L: length, RUE: radiation use efficiency, WUE: water use efficiency.
CONCLUSION AND SUGGESTION

Our findings suggest that conventional tillage out performed minimum tillage and no-tillage regarding yield by boosting FWPP, NFPP, L, D, and S. Consequences of conventional tillage such as improved bulk density, moisture retention, and weed suppression could have led to better NFPP and FI, resulting in higher yield in CT plots. The results indicate that conventional tillage (one pass with a moldboard followed by two passes with a disk harrow) can improve melon yield in regions with similar climates to that of the study area.

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