Nitrogen and irrigation water management in corn (Zea mays) under no-tillage and conventional tillage systems

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ABSTRACT

Organic carbon and irrigation water scarcity are two major limiting factors in corn (Zea mays L.) production of Fars province which is located in the south of Iran. Soil tillage systems can affect the nitrogen and water utilization. In 2015-2017, by using the strip-split plot design and two line-source sprinkler irrigation systems, effects of 0, 90, 180, and 270 kg ha⁻¹ of pure nitrogen and 6400, 7500, 8550, and 9600 m³ ha⁻¹ of irrigation water in conventional, and no-tillage systems were investigated. Results showed that conventional tillage system had high WUE and foliage yield than no-tillage systems. Based on the obtained results, in the terms of dry foliage yield, combined application of 8550 m³ ha⁻¹ irrigation water and 90 kg N ha⁻¹ (I290 treatment) are introduced as the superior treatments in both of two tillage systems. While, in terms of WUE, combined application of 8550 m³ ha⁻¹ irrigation water and 90 kg N ha⁻¹ (I290 treatment) in conventional tillage and combined application of 7500 m³ ha⁻¹ irrigation water and 135 kg N ha⁻¹ (I3135 treatment) in no-tillage systems are introduced as the superior treatments.

Key words: Conservation tillage, Irrigation, Maize, Nitrogen, WUE

Fars province located in the south of Iran and based on Koppen Climate classification system has mostly arid and semi-arid climate (Nasseri et al. 2017). Corn (Zea mays L.) is one of the most important crops cultivated in Fars province but its production in this province is limited by water and nitrogen. Austin (2011) reported that drought and nutrient deficiency are the main factors effect on crop production in arid and semi-arid areas. Conservation tillage practices by enhancing soil fertility, reducing seasonal evapotranspiration and conserving more soil water can effect on crop yields (Lampurlanes et al. 2016). Lenka et al. (2012) reported that tillage practices by affecting on the soil macro pores characteristics influenced soil moisture conservation and distribution. Tillage also by affecting on water infiltration can affect nitrate-N concentration, water contents, aeration, available of organic carbon, soil temperature, infiltration and evapotranspiration processes (Shao et al. 2016). The crop residues in conservation tillage are the direct sources of organic carbon. Decomposition of crop residues in conservation tillage is an effective practice that can improve soil properties and support crop production (Wang et al. 2015). A large number of studies have shown that conservation tillage practices have produced favorable benefits, including improved soil organic contents as well as increased crop yield and water use efficiency (Mazzoncini et al. 2016). Singh et al. (2016) believed that conservation tillage practices improved soil physical status like soil density, soil porosity, field capacity. In contrast, some limitations such limited root growth due to soil compaction in the no-tillage system, can lead to reduced contact between the crop roots and the soil in the root zone, and may decrease plant water and nutrients absorption (Zhang et al. 2004). The dominant factors affecting crop production in south of Iran are low amounts of rainfall and of low amounts of organic carbon in agronomic soils. As soil tillage systems can affect the nitrogen and water utilization, the objective of this research was to study conventional and no-tillage systems effects on irrigation water use efficiency and yield of corn and determine optimum amounts of irrigation water and nitrogen rates in two tillage systems.

MATERIALS AND METHODS

This field study was conducted at Fars, Iran (29°77′N and 52°72′E) for two years from July 2015 to October 2017 on a fine, carbonatic, termic, Typic Haploxerepts soil. The site (1170 m altitude) with the temperature averages 16.5°C and an average annual rainfall of 308 mm has a semiarid climate.
climate. Each year, soil samples were collected from surface
horizon (0 - 30cm) of the soil. In soil samples, particle-size
distribution determined by hydrometer method (Gee and
Bauder 1986), TNV was determined by neutralization with
HCl (Loeppert and Suarez 1996) and organic carbon were
determined by Walkley Black method (Nelson and Sommers
1996). Available Zn, Fe, Mn, and Cu were determined by
DTPA extraction (Lindsay and Norvell 1978), phosphorus
were determined by sodium bicarbonate extraction (Olsen
et al. 1954) and potassium were determined by NH₄OAc-K
extraction.

The field experiment was established as a strip split-
split plot design with 3 replicates for a total of 192 plots.
The main plots (48 m × 48 m) were conventional tillage
(Ct) and no-tillage (nt). Subplots (24 m × 48 m) were 0,
90, 135, and 180 kg. N ha⁻¹ as urea and sub-subplots (12
m × 48 m) were set at 9600 (I₁), 8550 (I₂), 7500 (I₃), and
6400 (I₄) m³.ha⁻¹ during the growing season.

In both two years, tillage treatments were conducted
after the harvest of previous wheat crops according to the
designed patterns. No tillage operations were carried out in
the no-tillage system and a moldboard plow, a disk harrow,
and a leveler were employed for the conventional tillage.
A seed drill was used for all two tillage systems to plant
corn (sc.704).

The irrigation treatments were applied using two line-
source sprinkler irrigation systems (Hanks et al. 1976).
For this purpose, 8 Nelson F33 sprinklers with about 12
m sprinkling radius at a distance of 6 m from each other
were mounted on risers of 150 cm height installed on a 75
mm polyethylene pipeline. As the sprinkling radius was
12 m, 4 treatments (I₁ to I₄) were located 0-3, 3-6, 6-9,
and 9-12 m apart on both sides of the main pipeline and
perpendicular to it. Therefore, each plot was 3*3 m². The
amount of irrigation water was calculated through measuring
soil moisture in treatment I₁ one day before irrigation using
the following equation [1]:

\[ I = \frac{[\theta_F - \theta_p] D}{100} \]  

(1)

where, \( I \) is the depth of irrigation water (cm), \( \theta_F \) is
the gravimetric soil moisture content at field capacity (%), \( \theta_p \)
is the available gravimetric soil moisture (cm), and \( D \) is the
effective root depth (30 cm). The irrigation interval was 8 days and the volume of
irrigation water was measured by a flow meter using a catch
can. The total water collected in each catch can was then
determined during the growing season. Water use efficiency
(WUE) was determined using the following equation (Zhao
et al. 2019):

\[ WUE = \frac{\text{Yield (kg.ha}^{-1}\text{)}}{\text{water used (m}^3\text{.ha}^{-1}\text{)}} \]  

(2)

The amount of nitrogen required for each treatment plot

Table 1 Means of some soil physical and chemical characteristics at the experimental field

<table>
<thead>
<tr>
<th>Ec</th>
<th>pH</th>
<th>T.N.V.</th>
<th>O.C.</th>
<th>P</th>
<th>K</th>
<th>Mn</th>
<th>Fe</th>
<th>Zn</th>
<th>Fe</th>
<th>PWP</th>
<th>BD</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>(dS.m⁻¹)</td>
<td>(g.100g⁻¹)</td>
<td>(mg.kg⁻¹)</td>
<td>(%)</td>
<td>(g.cm⁻³)</td>
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</tr>
<tr>
<td>1.31</td>
<td>8.1</td>
<td>32.0</td>
<td>0.60</td>
<td>8.5</td>
<td>224</td>
<td>7.7</td>
<td>5.0</td>
<td>0.66</td>
<td>21</td>
<td>11</td>
<td>1.6</td>
<td>SiCIL</td>
</tr>
</tbody>
</table>

Table 2 Results of chemical analysis of water used for field irrigation

<table>
<thead>
<tr>
<th>pH</th>
<th>EC</th>
<th>HCO₃⁻</th>
<th>Cl⁻</th>
<th>HBO₃⁻</th>
<th>SO₄²⁻</th>
<th>Total anion</th>
<th>Mg²⁺</th>
<th>Ca²⁺</th>
<th>Na⁺</th>
<th>Total cation</th>
<th>SAR</th>
</tr>
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<tr>
<td>(dS.m⁻¹)</td>
<td>(meq.l⁻¹)</td>
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</tr>
<tr>
<td>8.0</td>
<td>0.48</td>
<td>2.3</td>
<td>1.1</td>
<td>-</td>
<td>1.1</td>
<td>4.5</td>
<td>1.0</td>
<td>2.2</td>
<td>1.8</td>
<td>5.0</td>
<td>0.62</td>
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Table 3 Main effects of various tillage systems on the different parameters

<table>
<thead>
<tr>
<th>Tillage treatment</th>
<th>Plant height (cm)</th>
<th>Stem diameter (mm)</th>
<th>No. of plants.m⁻²</th>
<th>Fresh yield (t.ha⁻¹)</th>
<th>Dry yield (t.ha⁻¹)</th>
<th>Soil OC (g.100g⁻¹)</th>
<th>Foliage N uptake (kg. ha⁻¹)</th>
<th>WUE (kg.m⁻³. ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014-2015</td>
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<td></td>
</tr>
<tr>
<td>conventional tillage (CT)</td>
<td>248</td>
<td>20.7</td>
<td>8.89</td>
<td>63.875</td>
<td>38.906</td>
<td>0.883</td>
<td>448</td>
<td>4.93</td>
</tr>
<tr>
<td>No tillage (NT)</td>
<td>223</td>
<td>26.2</td>
<td>7.84</td>
<td>50.292</td>
<td>29.146</td>
<td>1.147</td>
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<td>3.69</td>
</tr>
<tr>
<td>2015-2016</td>
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<td>conventional tillage (CT)</td>
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<td>8.07</td>
<td>57.521</td>
<td>39.659</td>
<td>0.893</td>
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<td>4.96</td>
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<td>No tillage (NT)</td>
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<td>19.4</td>
<td>7.73</td>
<td>54.667</td>
<td>34.884</td>
<td>1.104</td>
<td>370</td>
<td>4.42</td>
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<tr>
<td>2014-2016</td>
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<td></td>
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<tr>
<td>conventional tillage (CT)</td>
<td>248 a</td>
<td>20.38 b</td>
<td>8.48 a</td>
<td>60.698 a</td>
<td>39.283 a</td>
<td>0.888 b</td>
<td>440 a</td>
<td>4.95 a</td>
</tr>
<tr>
<td>No tillage (NT)</td>
<td>234 b</td>
<td>22.80 a</td>
<td>7.79 b</td>
<td>52.479 b</td>
<td>32.015 b</td>
<td>1.126 a</td>
<td>351 b</td>
<td>4.06 b</td>
</tr>
<tr>
<td>Anova</td>
<td>8843**</td>
<td>280**</td>
<td>23.0**</td>
<td>3242**</td>
<td>2535**</td>
<td>0.04**</td>
<td>377454**</td>
<td>37.91**</td>
</tr>
</tbody>
</table>

Similar letters in each column represent insignificant differences between the two treatments related to the parameter.
<table>
<thead>
<tr>
<th>Plant height (cm)</th>
<th>Stem diameter (mm)</th>
<th>No. of plants per m²</th>
<th>Fresh yield (t ha⁻¹)</th>
<th>Dry yield (t ha⁻¹)</th>
<th>OC post harvesting (g 100g⁻¹)</th>
<th>Foliage N uptake (kg ha⁻¹)</th>
<th>WUE (kg m⁻³ ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>Nitrogen</td>
<td>I * N* t</td>
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<tr>
<td>I1</td>
<td>n0</td>
<td>245b</td>
<td>21.95</td>
<td>34.82a</td>
<td>39.617ab</td>
<td>41.38bd</td>
<td>4.91c</td>
</tr>
<tr>
<td></td>
<td>n90</td>
<td>245a</td>
<td>21.95</td>
<td>36.82abc</td>
<td>39.054ad</td>
<td>44.32ad</td>
<td>5.08a</td>
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<tr>
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<td>5.08a</td>
</tr>
</tbody>
</table>

Similar letters in each column of irrigation, Nitrogen and Irrigation * Nitrogen represent insignificant differences between the two treatments related to the parameter.
in each tillage system was applied to the soil at planting time, at V3 stage, and at V10 stage. Based on the soil test results, triple superphosphate and zinc phosphate were uniformly applied to each treatment plots at 200 and 40 kg.ha\(^{-1}\), respectively.

In the harvesting time, plant height, stem diameter and numbers of plants in square meter, soil organic carbon and wet foliage yields of each plot were measured. The wet foliage were dried at 65-70°C to find out dry foliage yield. In dry foliage, concentration and uptake of N, P, K and Zn were measured. Measured parameters as well as water use efficiency was evaluated with SAS version 9.2 (analysis of variance). When main effects were significant, the means were compared by using Duncan’s multiple range tests.

RESULTS AND DISCUSSION

Tillage had a significant effect on the plant height, stem diameter, number of plant.m\(^{-2}\), fresh and dry yield, N uptake by foliage and soil organic carbon after harvesting (Table 3). As the mean plants height and number of plants per square meter were significantly higher in CT than NT (by 5.6% and 8.1%, respectively), the fresh and dry foliage yield was higher in CT than in NT by 13.5 and 24.8% (Table 3). This result is in accordance with Zhang et al. (2018) and Ziaeian et al. (2019) who reported that the corn yield in conventional tillage was more than no-tillage. Based on Jin et al. (2017) reports deep ploughing in conventional tillage can decrease subsoil density, thereby increase soil water storage and crop yield. Van den Putte et al. (2010) believed that limited root growth due to soil compaction in the no-tillage system, can lead to reduced contact between the crop roots and the soil in the root zone, and may decrease plant water and nutrients absorption. In contrast with our results, Rani et al. (2019) reported that there were no statistical differences between conservation and conventional tillages in terms of grain yield. Singh et al. (2016) also believed that conservation tillage improved soil physical status like soil density, soil porosity and field capacity and Chen et al. (2015) reported that conservation tillage practices could capture rainfall effectively and could improve soil water and then improved crop yield.

Tillage also had a significant effect on water use efficiency. On the average over two experimental years, WUE was higher in CT than in NT by 18.0% (Table 3). Overall, conventional tillage system with average yield 39283 kg.ha\(^{-1}\) and WUE average 4.95 kg.m\(^{-3}\).ha\(^{-1}\) was significantly superior to no-tillage system by average yield 32015 kg.ha\(^{-1}\) and average WUE of 4.06 kg.m\(^{-3}\).ha\(^{-1}\) (Table 3). Various tillage can increase soil water content (Sharma et al. 2011). There are sufficient pore spaces in conventional tillage which causes a better development of the tap root (Van den Putte et al. 2010). Another possible explanation for WUE in conventional tillage is that deep ploughing can decrease subsoil density, thereby increase soil water storage and crop yield (Jin et al. 2017). In contrast, conventional tillage may have negative effects on water productivity and yield (Alletto et al. 2011). It has been shown that WP can be improved by conservation tillage system such as no-tillage and reduced tillage systems and these systems are more useful and more effective in reducing soil erosion (Mohammadi 2012, Safari et al. 2013). Shao et al. (2016) reported that conventional tillage without straw mulching, which is widely used in semi-arid region, remarkably increased soil water loss via evaporation.

Combined effects of irrigation water, nitrogen and tillage systems on the yield contributing characters are presented in Table 4. In general, the amounts of plants height, number of plants per square meter, yield and WUE in CT were higher than NT in the same treatments so that in I2N180 treatment, amounts of plant height and number of plants per square meter, fresh and dry foliage yield and WUE in conventional tillage were higher than to no-tillage system by 8.6, 9.8, 13.2, 16.9 and 16.9 %, respectively. It has been reported that yield is a function of photosynthesis rate. Water stress resulting in reduced photosynthesis.

Reduced photosynthesis reduces yield (Mafakheri et al. 2010). Drought stress reduces stomata conductance and net photosynthesis, shortens plant growth and ultimately reduces yield (Rajjala et al. 2009). Nitrogen application also had significant effects on yield and WUE. Azizian and Sepaskhah (2014) reported that nitrogen by influencing on cell division and by helping absorption of other nutrients increased plant growth. Subedi et al. (2007) reported that application of sufficient nitrogen leads to increased root growth and improved capability to absorb water from the deeper soil layers under drought conditions.

Conclusion

Tillage systems affected the irrigation and nitrogen application rates, yield and water use efficiency (WUE). The maximum dry foliage yield in conventional (CT) and in no-tillage systems (NT) (48783 and 38405 kg.ha\(^{-1}\), respectively) were obtained from combined application of 8550 m\(^{3}\).ha\(^{-1}\) irrigation water and 90 kg N.ha\(^{-1}\) (I2N90) and combined application of 8550 m\(^{3}\).ha\(^{-1}\) irrigation water and 135 kg N.ha\(^{-1}\) (I2N135) treatments, respectively, which are recommendable in the same conditions. The maximum WUE in CT (5730 kg.m\(^{3}\).ha\(^{-1}\)) were obtained from I2N90 treatment and in NT (4520 kg.m\(^{3}\).ha\(^{-1}\)) were obtained from combined application of 7500 m\(^{3}\).ha\(^{-1}\) irrigation water and 90 kg N.ha\(^{-1}\) (I3N90) or combined application of 6400 m\(^{3}\).ha\(^{-1}\) irrigation water and 90 kg N.ha\(^{-1}\) (I4N90) treatments. In general, combined application of 90 kg N.ha\(^{-1}\), and 8550 m\(^{3}\).ha\(^{-1}\) of irrigation water and combined application of 135 kg N.ha\(^{-1}\) and 7500 m\(^{3}\).ha\(^{-1}\) irrigation water are introduced as the superior treatment in conventional tillage and in no-tillage systems, respectively.

REFERENCES


