Management of Water-Nitrogen Units under Different Deficit Irrigation Strategies for Zea maize Crop

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ABSTRACT

Drip irrigation method can be more efficient than other types of irrigation methods, such as surface flood irrigation or sprinkler irrigation. Field experiments were carried out at the experimental farm, Faculty of Agric., Tanta Univ., Egypt, during summer seasons of 2018 and 2019 due to the limited water, as it is an important factor for agriculture expansion with the aim of providing water and fertilizer and improving the water distribution uniformity. Maize crop (Triple Hybrid 321). The factors of study were three laters' positions; these positions were lateral line directly beside crop row (FI); lateral line was placed at 15 cm from crop row (PRD1) and alternate partial root zone drying at 15 cm from crop row (APRD2). Three irrigation water regimes noted: (100, 75 and 50% of the ETc). Three rates of nitrogen fertilization were used (100% "600kg", 50% "300kg" and 0% "control" of kg N ha⁻¹). The results indicated that the maximum yield of maize crop was obtained from the maximum nitrogen level (100%) and when the lateral placement was directly next to the crop row. The minimum maize crop yield was achieved using nitrogen fertilization (0%) and lateral positioning 15 cm away from the plant line. The chlorophyll content is affected by the nitrogen fertilization level and lateral positions. PRD2 and PRD1 these lateral positions increase the chlorophyll content compared to FI as, the highest values were 41.7 and 40.7 were recorded at PRD2=100%N and PRD1+50%N respectively. The distribution uniformity value was high at 200kPa and the distribution uniformity values were low at 50 and 100kPa respectively.

Keywords: drip irrigation; partial root zone drying; lateral positions; nitrogen fertilization; evapotranspiration; and chlorophyll content.

INTRODUCTION

The availability of water is a key factor for agricultural development processes under arid regions. The world's population is continuously increasing; while the world renewable water resources are limited and become more scarce and therefore more water for domestic, industrial, environmental, recreational and agricultural needs is needed. While water is very abundant in global scale, but 97% is saline, 2.25% is glacier and just 0.75% is available as freshwater in watersheds, rivers and lakes (FAO, 2003).

Maize is the third most important food crop after rice and wheat, in terms of global production (USDA, 2011). Maize is an important crop for the Egyptian national economy, because it is an origin of food for humans Egypt's maize production has risen dramatically over the last three decades.

Besides, integrated application of PRD and drip irrigation method reduces water use by 50% which increases water use efficiency by 80–92% (Götur et al., 2018). Surface irrigation is a commonly used and well-known method that does not need any high-tech applications to function. It needs more effort than other irrigation methods in general. One of the major problems of surface irrigation is the low efficiency which effects on food quality.

Drip irrigation is a form of micro irrigation device that allows water to drip slowly to the roots from above the soil surface or submerged below the surface, potentially saving water and nutrients. The aim is to get water into the root zone quickly to reduce evaporation. In order to increase water use efficiency and to shift to a more sustainable use of water in agriculture, enhanced water use efficiency is crucial (Bartua et al., 2018).

The combined irrigation and fertilization has been widely used for the cultivation of crops and fruit orchards all over the world (Yan et al., 2018). Drip irrigation is more appropriate for applying fertigation. Thus, the soluble fertilizers at any concentrations needed by crops can be applied through irrigation systems to wetted zones of soil (Chartzoulakis and Bertaki, 2015). Uhart and Andrade (1995) indicated that the grain yield of maize was reduced by low application of N. Kirda et al. (2005) reported that Partial Root Drying "PRD" improved N fertilizer recovery in maize resulting in lower mineral N left in the soil as compared with fully "FT" and deficit irrigation "DI" treatments.

The availability of water is a limiting factor for agriculture expansion, therefore the water should be saved by using a new partial root zone drying is an irrigation procedure. PRD is an irrigation method that irrigates half of the root zone while allowing the other half to dry out.

The overall aim of this research study was to save water and fertilizer by using PRD and increase maize productivity.

MATERIALS AND METHODS

Two successive field experiments were carried out over the summer seasons of 2018 and 2019 at the experimental farm of the Faculty of Agriculture, Tanta University. The experimental field soil was classified as clay loam in texture. The area of the experiment was about 1050 m². "Fig. 1" the experiments included the combinations of three laterals placements (lateral line directly beside crop row, FI; lateral line was placed at 15 cm from the crop row, PRD1 and lateral line was moved each 15 days and far from plant line by 15 cm "PRD2"). In addition to three levels of ETc (100%, 75% and 50%), three rates of nitrogen fertilization (100%, 50% and 0%) were used. A surface drip irrigation...
irrigation network was used to irrigate corn which had a mainline buried under the soil surface which delivers water from the submain lines. The main line made from PVC, of 63mm in diameter and 21m long. Two valves were installed at the to control water flow from mainlines to submainlines.

**Sub-main lines:** Sub main lines located under the ground surface carry water from the mainline to the laterals. Sub main lines made from PVC, 63mm in diameter and 35m long.

**Lateral lines:** Lateral lines located on the ground surface carry water from the sub main lines to the emitters. Lateral lines were made from PE, 16mm in diameter and the distance between each two laterals was 0.5m.

**Emitters:** Emitter type was "In line" and non-compensating emitters. The distance between each two emitters was 0.5m and the emitter discharge was 4L/h at operating pressure of one bar.

Nitrogen fertilization was applied at a rate of 15g/m² per plant, as they were added in three stages during the growing season. Irrigation was carried out twice a week at a rate of two hours for 100% of ETe, an hour and a half and 75% of the ETe and an hour for 50% of the ETe.

The concentration of chlorophyll in plant leaves was determined using this method. The SPAD stands for Soil-Plant Analysis Growth, and it calculates chlorophyll content by measuring leaf absorbance in the red and near-infrared range. A measuring tape was used to measure the plant height. Plant height was measured every 10 days during the first and second season of maize crop.

The discharge coefficient of variation for the emitters was calculated by using the following equation according to ASAE (1991):

\[
CV = \frac{s}{q} \times 100 \quad [1]
\]

Where:
- \(CV\) = manufacturing coefficient of variation in %
- \(s\) = standard deviation of emitters flow rate
- \(q\) = emitter flow rate average, L/h.

A random sample of emitters may be chosen and the discharge intensity measured at the same temperature and pressure to determine the discharge coefficient of variation. One of the important parameters concerning the overall uniformity and performance of a drip irrigation system is the discharge coefficient of manufacturing heterogeneity. The International Standard contains a number of recommendations and instructions (1991) as shown in Table 1. Emitters in category "A" have the maximum emission rate uniformity and the smallest divergence from the required nominal emission rate. Emitters in category "B" have a medium level of emission rate uniformity and a medium divergence from the nominal emission rate. Emitters in category "C" have the least consistent emission rates and the highest divergence from the nominal emission rate.

Bralts et al. (1981) emphasized the use of the statistical uniformity coefficient "Us" for determining drip irrigation lateral line pattern uniformity, including manufacturing variance. Bralts and Kesner (1982) the use of the statistical uniformity coefficient is simple and precise, according to the analysis. The following equation can be used to determine the statistical uniformity coefficient:

\[
Us = (1 - CV) \times 100 \quad [2]
\]

Where:
- \(Us\) = the statistical uniformity coefficient in % and
- \(CV\) = the coefficient of variation

Table 1. Discharge coefficient of variation "CV" values of emitters according to ISO norm:

<table>
<thead>
<tr>
<th>Category</th>
<th>Discharge coefficient of variation, %</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Good</td>
<td>0 to ± 5</td>
</tr>
<tr>
<td>B</td>
<td>Medium</td>
<td>± 5 to ± 10</td>
</tr>
<tr>
<td>C</td>
<td>Poor</td>
<td>&gt; 10</td>
</tr>
</tbody>
</table>

The distribution uniformity is a useful indicator of distribution problems. The following equation was used to calculate distribution of uniformity (DU) according to Anon. (1978).

\[
DU = \left( \frac{q_{1/4}}{q} \right) \times 100 \quad [3]
\]

Where:
- \(DU\) = distribution uniformity in %
- \(q_{1/4}\) = mean of lowest one-fourth of emitter flow rates in L/h and
- \(q\) = average emitter flow rates L/h.

**RESULTS AND DISCUSSION**

The influence of nitrogen levels "100%, 50% and 0%" on plant height for different levels of ETe"100%, 75%, and 50%" is illustrated in Fig. 2. The plant height in full irrigation "FI" was too high for 100%N, 75%ETe and was too low for 100%N, 100%ETe.

The relationship between lateral placement "FI, PRD1 and PRD2" and the plant height for nitrogen levels "100%, 50% and 0%" is shown in Fig. 3. The lateral placement and nitrogen fertilization generally did not highly effect on plant height.
operating pressure leads to distribution uniformity increase. (Solomon, 1977). These results showed that increases in manufacturer's respectively. To achieve fair water application uniformity, the distribution uniformity values were low at 50kPa and 100kPa fig. 100kPa

Thus, nitrogen fertilization enhanced maize yield. The influence of nitrogen levels 100%N+PRD1 and the lowest productivity was recorded at “0%N+PRD2”. That is in PRD2 the chlorophyll content decreases with low levels of added nitrogen.

The influence of nitrogen levels 100% (200kg N ha⁻¹), 50% (100kg N ha⁻¹) and 0% on the productivity of maize crop for different positions of laterals “FI, PRD1 and PRD2” is illustrated in Fig.5. The greatest crop yield of maize was recorded with the combination of “100%N+ FI” and the lowest productivity was recorded at “0%N+PRD2”. Thus, nitrogen fertilization enhanced maize yield.

The relationship between operating pressure (50kPa-100kPa-200kPa) and distribution uniformity (%) is illustrated in fig. 6. The distribution uniformity value was high at 200kPa and the distribution uniformity values were low at 50kPa and 100kPa respectively. To achieve fair water application uniformity, the manufacturer's coefficient of difference should be 15% or less (Solomon, 1977). These results showed that increases in operating pressure leads to distribution uniformity increase.
Table 4. Analysis of variance for biomass treatment "ANOVA"

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of freedom</th>
<th>Sum of squares</th>
<th>Mean square</th>
<th>F value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>2</td>
<td>272795.877</td>
<td>136397.934</td>
<td>1.3408</td>
<td>0.3584</td>
</tr>
<tr>
<td>Factor A</td>
<td>2</td>
<td>1892678.009</td>
<td>946393.049</td>
<td>9.3025</td>
<td>0.0313</td>
</tr>
<tr>
<td>Error</td>
<td>4</td>
<td>409616.864</td>
<td>102179.216</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Factor B</td>
<td>2</td>
<td>462065.691</td>
<td>231028.346</td>
<td>5.2828</td>
<td>0.0226</td>
</tr>
<tr>
<td>AB</td>
<td>4</td>
<td>594964.049</td>
<td>148741.012</td>
<td>3.4012</td>
<td>0.0444</td>
</tr>
<tr>
<td>Error</td>
<td>12</td>
<td>527490.370</td>
<td>43732.312</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Factor C</td>
<td>2</td>
<td>141639.210</td>
<td>70819.605</td>
<td>1.2800</td>
<td>0.2904</td>
</tr>
<tr>
<td>AC</td>
<td>4</td>
<td>45242.420</td>
<td>11310.605</td>
<td>0.2044</td>
<td>NS</td>
</tr>
<tr>
<td>BC</td>
<td>4</td>
<td>118262.271</td>
<td>29570.568</td>
<td>0.5345</td>
<td>NS</td>
</tr>
<tr>
<td>ABC</td>
<td>8</td>
<td>747459.877</td>
<td>93094.985</td>
<td>1.6827</td>
<td>0.1365</td>
</tr>
<tr>
<td>Error</td>
<td>36</td>
<td>1991726.222</td>
<td>55235.728</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Total | 80 | 7198551.951 | |

The results indicated that the maximum yield of maize crop (kg/fed) was obtained from the maximum nitrogen level "100%N" and when the lateral placement was directly next to the crop row. The minimum yield of maize (kg/fed) was obtained at nitrogen fertilization "0%" with alternate partial root drying treatment. Plant height was affected by the ETc level, where the plant height was increased at 75%ETc and was low at 100%ETc. Plant height is also affected by the position of drip line, where the maximum plant height (cm) was recorded with the normal position "the drip line was just next to the crop row. The minimum plant height (cm) was at PRD2 "the drip line was far 15cm from the crop row. Also, plant height is not significantly affected by nitrogen fertilization. The chlorophyll content is affected by the nitrogen fertilization level, where the highest chlorophyll content (%) was at 100%N and the lowest chlorophyll content (%) was at 0%N. That means that when the nitrogen level increased, the chlorophyll content of corn leaves increased. In conclusion maize yield and water use efficiency could be maximized when optimized irrigation regime and nitrogen fertilization rate associated with efficient irrigation technique. The distribution uniformity value was at 200Pa and the distribution uniformity values were at low 50Pa and 100Pa respectively. To achieve fair water application uniformity, the manufacturer's coefficient of difference should be 15% or less. Increases in operational demand often result in increased distribution uniformity, according to the results.

CONCLUSION

The results indicated that the maximum yield of maize crop (kg/fed) was obtained from the maximum nitrogen level "100%N" and when the lateral placement was directly next to the crop row. The minimum yield of maize (kg/fed) was obtained at nitrogen fertilization "0%" with alternate partial root drying treatment. Plant height was affected by the ETc level, where the plant height was increased at 75%ETc and was low at 100%ETc. Plant height is also affected by the position of drip line, where the maximum plant height (cm) was recorded with the normal position "the drip line was just next to the crop row. The minimum plant height (cm) was at PRD2 "the drip line was far 15cm from the crop row. Also, plant height is not significantly affected by nitrogen fertilization. The chlorophyll content is affected by the nitrogen fertilization level, where the highest chlorophyll content (%) was at 100%N and the lowest chlorophyll content (%) was at 0%N. That means that when the nitrogen level increased, the chlorophyll content of corn leaves increased. In conclusion maize yield and water use efficiency could be maximized when optimized irrigation regime and nitrogen fertilization rate associated with efficient irrigation technique. The distribution uniformity value was at 200Pa and the distribution uniformity values were at low 50Pa and 100Pa respectively. To achieve fair water application uniformity, the manufacturer's coefficient of difference should be 15% or less. Increases in operational demand often result in increased distribution uniformity, according to the results.

REFERENCES


