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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 Agri., 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 laterals' 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 15cm 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 and100kPa respectively.

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

INRTODUCTION

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% (Gotur 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 (Barua 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 "FI" 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 m^2. "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

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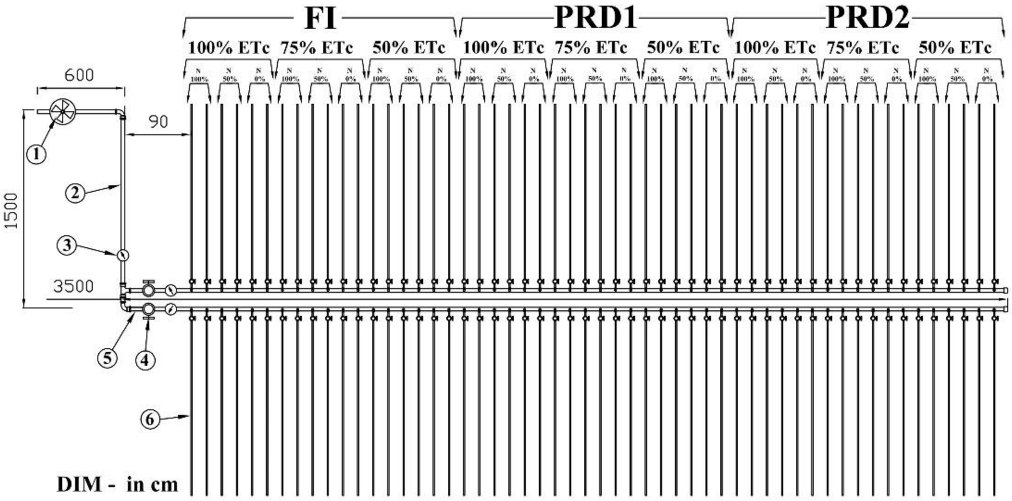
irrigation network was used to irrigate corn which had a mainline buried under the soil surface which delivers water from the sub-main lines. The main line made from PVC, of 63mm in diameter and 21m long. Two valves were installed at the to control water flow from mainlines to sub mainlines.

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 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 15gm 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 ETc, an hour and a half to 75%of the ETc and an hour for 50% of the ETc.



1-Water sour **2-Main line** **3-Pressure gauge** **4-T-shape valve** **5-Submain line** **6-Lateral's line**

Fig. 1. The experimental treatments layout

A portable SPAD Chlorophyll meter (Minolta, Japan) 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):

$$\mathbf{C.V} = \frac{s}{q'} \times \mathbf{100} \qquad [1]$$

Where:
C.V= manufacturing coefficient of variation in %;
S= standard deviation of emitters flow rate and
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:

$$\mathbf{U_s} = (\mathbf{1} - \mathbf{CV}) \times \mathbf{100} \qquad [2]$$

Where:
U_s=the statistical uniformity coefficient in % and
CV= the coefficient of variation

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

Category	Discharge coefficient of variation, %	Classification
A	0 to ± 5	Good
B	± 5 to ± 10	Medium
C	> 10	Poor

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).

$$\mathbf{DU} = \left(\frac{\bar{q}_{Iq}}{\bar{q}}\right) \times \mathbf{100} \qquad [3]$$

Where:
DU = distribution uniformity in %,
$\bar{q}_{Iq}$ = mean of lowest one-fourth of emitter flow rates in L/h and
$\bar{q}$ = 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 ETc"100%, 75%, and 50%" is illustrated in Fig.2. The plant height in full irrigation "FI" was too high for 100%N, 75%ETc and was too low for 100%N, 100%ETc.

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.

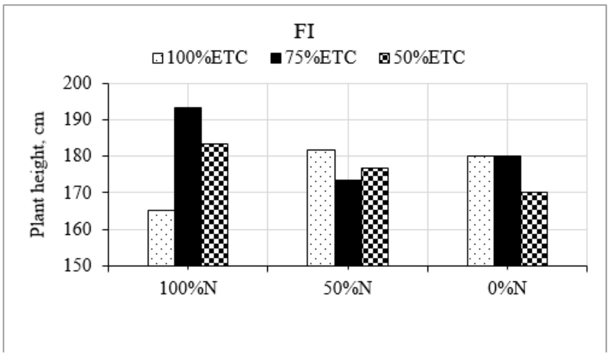


Fig. 2. The influence of nitrogen levels on plant height

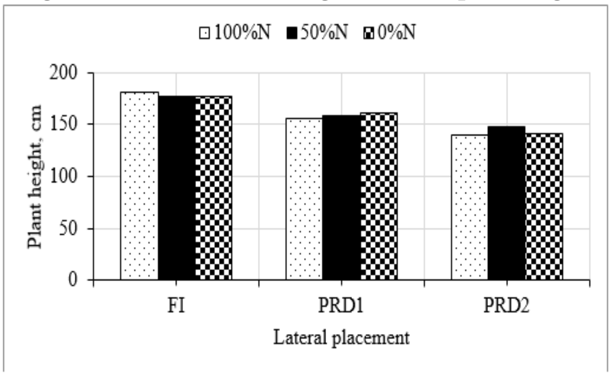


Fig. 3. The influence of lateral placement and nitrogen fertilization on plant height

The influence of nitrogen levels (100%N-50%N-0%N) on chlorophyll content for different lateral placement (FI-PRD1-PRD2) are illustrated in Fig. 4. The greatest chlorophyll content was recorded with the combination of PRD2+100%N and the least chlorophyll content was for the treatment which combination of PRD2+0%N. That is in PRD2 the chlorophyll content decreases with low levels of added nitrogen.

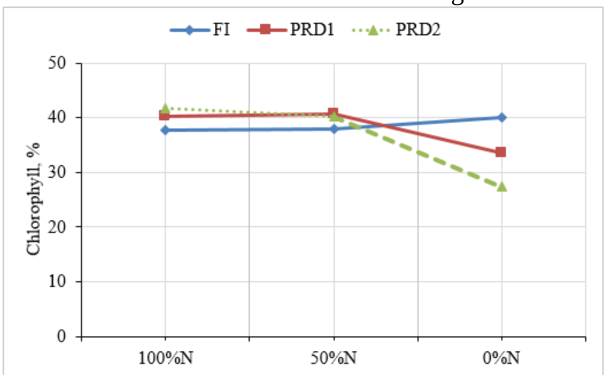


Fig. 4. The influence of nitrogen levels on chlorophyll content

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.

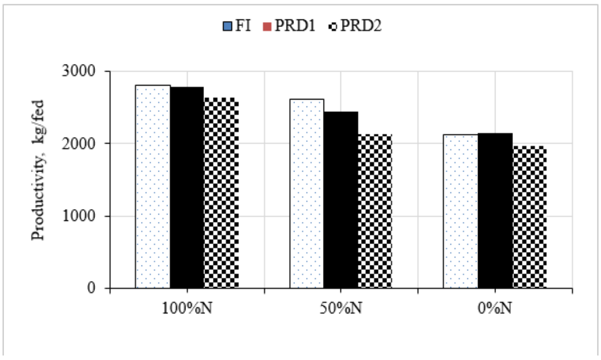


Fig. 5. The influence of nitrogen levels on the maize productivity

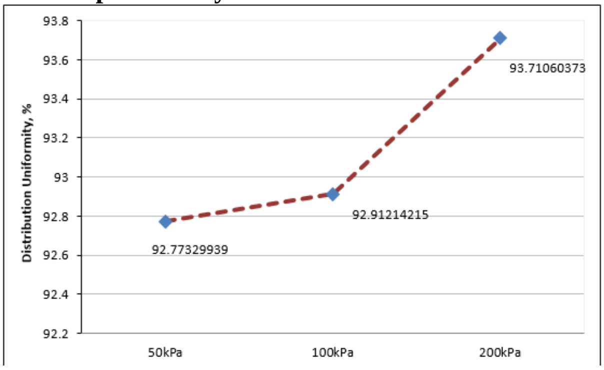


Fig. 6. The relationship between pressure and distribution uniformity

The general characteristics of the tested emitters are shown in Table 2 such as nominal discharge, actual discharge, coefficient of variation, statistical uniformity coefficient and emitter flow variation. A statistical analysis was done and it was found that there were no significant differences for the root size in different treatments as shown in Table 3. It was also noticed that there were no significant differences for the biomass of the crop under study at nitrogen levels, interaction between lateral position and nitrogen levels, interaction between ETc and nitrogen levels, and interaction between lateral position, ETc and nitrogen levels. However, there were significant effects of lateral position, nitrogen levels, and interaction between lateral position and ETc levels on biomass as shown in Table 4.

Table 2. The general characteristics of the tested emitters at different pressures

Pressure (kPa)	Nominal discharge (L/h)	Tested discharge (L/h)	Coefficient of variation (%)	Statistical uniformity coefficient (%)	Emitter flow variation (%)
50	--	2.95	6.66%	-566	18.40
100	4	4.22	6.55%	-555	17.46
200	4.6	5.95	5.85%	-485	17.62

Table 3. Analysis of variance for root size treatment "ANOVA"

Source	Degrees of freedom	Sum of squares	Mean square	"F" value	Probability	
Replication	2	83.154	41.577	1.8723	0.2668	
Factor A	2	189.673	94.836	4.2706	0.1017	NS
Error	4	88.827	22.207			
Factor B	2	557.784	278.892	1.2228	0.3286	NS
AB	4	1105.420	276.355	1.2117	0.3561	NS
Error	12	2736.963	228.080			
Factor C	2	519.154	259.577	1.7454	0.1890	NS
AC	4	885.160	221.290	1.4880	0.2263	NS
BC	4	140.160	35.040	0.2356		NS
ABC	8	1055.469	131.934	0.8871		NS
Error	36	5353.889	148.719			
Total	80	12715.654				

Table 4. Analysis of variance for biomass treatment "ANOVA"

Source	Degrees of freedom	Sum of squares	Mean square	"F" value	Probability	
Replication	2	272795.877	136397.938	1.3408	0.3584	
Factor A	2	1892678.099	946339.049	9.3025	0.0313	*
Error	4	406916.864	101729.216			
Factor B	2	462056.691	231028.346	5.2828	0.0226	*
AB	4	594964.049	148741.012	3.4012	0.0444	*
Error	12	524790.370	43732.531			
Factor C	2	141639.210	70819.605	1.2800	0.2904	NS
AC	4	45242.420	11310.605	0.2044		NS
BC	4	118282.272	29570.568	0.5345		NS
ABC	8	744759.877	93094.985	1.6827	0.1365	NS
Error	36	1991726.222	55325.728			
Total	80	7195851.951				

-Factor "A", lateral position; factor "B", ETc levels; and factor "C", nitrogen levels in Tables 3 and 4.

CONCLUSION

The results indicated that the maximum yield of maize crop (kg/fed) was obtained from the maximum nitrogen level "100%" 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 when the nitrogen level increased, the chlorophyll content of corn leaves increased. In conclusion maize yield and water use efficiency could be maximized when optimum irrigation regime and nitrogen fertilization rate associated with efficient irrigation technique. 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. Increases in operational demand often result in increased distribution uniformity, according to the results.

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أداره وحدات المياه والنيتروجين في ظل إستراتيجيات مختلفة لعجز الري لمحصول الذرة

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قسم الهندسة الزراعية – كلية الزراعة – جامعة طنطا

أجريت هذه الدراسة على نظام الرى بالتنقيط فى المزرعة البحثيةلكلية الزراعة جامعة طنطا، بهدف توفير المياه والسماد، عن طريق استخدام تقنية التجفيف الجزئى للجذور ومعرفة تأثير هذه التقنية على انتاجية الفدان لمحصول الذرة (هجين ثلاثى321) ،وأيضا تأثيرها على حجم الجذور للمحصول تحت الدراسة، لهذا تم استخدام ثلاثة أوضاع مختلفة لخطوط التنقيط وهي: خط تنقيط بجوار النبات مباشرة. خط تنقيط يبعد مسافة 15سم عن النبات وثابت خلال موسم التجربة. خط تنقيط يبعد 15سم عن النبات ويتم تغييره كل 15 يوم يمين ويسار النبات. أيضا تم استخدام ثلاثة مستويات من كميات المياه المضافة وهى: 100% من ETC ، 75% من ETC ، 50% من ETC كما أنه تم استخدام ثلاثة مستويات من التسميد النيتروجيني كنسبة من الإحتياجات السمادية القياسية وهي: 100% نيتروجين ، 50% نيتروجين ، صفر% نيتروجين. وتتلخص النتائج المتحصل عليها فى الأتى: أعلي انتاج لمحصول الذرة تم الحصول عليه من أقصى مستوى للنيتروجين وموضع خط التنقيط الأول "خط التنقيط بجوار خط النبات مباشرة" كما أن أقل انتاجية لمحصول الذرة كانت عند تطبيق أقل مستوى للنيترجين وخط التنقيط يبعد عن خط النبات 15سم ومتحرك خلال موسم النموأى أن التسميد النيتروجينى يعظم من الانتاج. ارتفاع النبات يتأثر بمستوى ETC حيث تم تسجيل أعلى ارتفاع للنبات عند 75%ETC بينما أقل ارتفاع للنبات كان عند 100%ETC. ارتفاع النبات أيضا يتأثر بموضع خط التنقيط حيث كان أقصى ارتفاع للنبات عند الوضع العادى "خط التنقيط بجوار النبات مباشرة" وأقل ارتفاع عند "PRD2" خط التنقيط يبعد عن النبات 15سم ومتحرك خلال موسم النمو. كما أن ارتفاع النبات لا يتأثر بشكل كبير بمستوى التسميد النيتروجينى. محتوى الكلورفيل في أوراق الذرةتأثر بمستوى التسميد النيتروجينى حيث كان أعلى محتوى للكلورفيل عند 100%N وأقل محتوى للكلورفيل عند 0%N. أى أنه بزيادة المستوى النيتروجينى إزداد محتوى الأوراق من الكلورفيل والعكس صحيح.