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EFFECT OF AIR INJECTION UNDER SUBSURFACE DRIP IRRIGATION ON YIELD AND WATER USE EFFICIENCY OF CORN IN SAND CLAY LOAM SOIL

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ABSTRACT

Subsurface drip irrigation (SDI) can substantially reduce the amount of irrigation water required for corn production. However, corn yield improvements applied will offset the initial cost of drip installation. The air-injection system is at least potentially applicable to (SDI) system. Consequently, the air affecting soil volume is probably limited to a chimney column directed above the emitter outlet. A field study was conducted in 2010 and 2011, to evaluate the effect of air-injection in SDI on the performance of corn. Experimental treatments were drip irrigation (DI), SDI, and SDI with air-injection. The results showed that the leaf area per plant was 1.477 and 1.0045 times greater with the aerated treatment than in DI and SDI respectively. Tuber bulking was faster, and terminated earlier under air-injected drip system, than in SDI and DI. Root distribution, stem diameter, plant height and number of grains per plant were noticed to be higher under air injection than DI and SDI. The Air-injection had the highest water use efficiency (WUE) and irrigation water use efficiency (IWUE) on both growing seasons, it was 1.442 and 1.096 kg m^{-3} in 2010 and 1.463 and 1.112 kg m^{-3} in 2011 for WUE and IWUE respectively. Comparing with the DI and SDI, the Air injection treatment achieved a significant higher productivity through the two seasons. Increasing of Air-injection treatment yield is 37.78% and 12.27% at 2010 and 38.46% and 12.5% at 2011 compared to the DI and SDI treatments respectively. Data from this study indicate that corn yield can be improved under SDI if the drip water is aerated.

Keywords: Drip irrigation, subsurface drip irrigation, aeration, corn, water use efficiency.

INTRODUCTION

Modifying root zone environment by injecting air has continued to intrigue investigators. However, the cost of a single purpose, air-only injection system, separate from the irrigation system, detracts from the commercial attractiveness of the idea.

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With the acceptance of subsurface drip irrigation (SDI) by commercial growers, the air injection system is at least potentially applicable to the SDI system. Unfortunately, when air alone is supplied to the SDI system is emited as a vertical "stream," moving above the emitter outlet directly to the soil surface. Consequently, the air affecting soil volume is probably limited to a chimney column directly above the emitter outlet. Balancing the air/water relationships as well as changing soil temperature could affect growing conditions and yield. Time consumed in aerating the irrigation water increases the potential for the air to travel with water movement within the root zone more generally and affect crop growth of harvest, particularly in locations with limited growing seasons.

The roots of most crop species need a good supply of oxygen in order to satisfy the water and nutrient needs of the shoots (***Meek et al., 1983***). Paradoxically, one of the first symptoms of excessive soil wetness is drought stress in the leaves. If these conditions are prolonged for more than a few days, then further serious damage can be affected via nutrient deficiency, build-up of metabolic poisons and increased incidence of root diseases (***Vartapetian and Jackson, 1997***).

Oxygen is essential for root respiration. Immediately after the roots have been surrounded by water they can no longer respire normally. The liquid impedes diffusion of metabolites such as carbon dioxide and ethylene. This causes the plant to be stunted because ethylene is a growth inhibitor (***Arkin and Taylor, 1981***). When air entrained into the water within the root zone, diffusion of ethylene and carbon dioxide away from the roots may be increased. This increased diffusion rate should result in improved growing conditions.

As drip irrigation develops a wetting front near emitters, the root zone of the crop remains near saturation for a portion of the time between irrigation events, especially on heavy cracking clay making them the least desirable soil types for drip irrigation. Particularly in poorly drained soils, flood irrigation and wet weather cause water to replace air in the soil thus reducing the availability and mobility of oxygen that remains trapped in soil pores (***Meek et al., 1983***). By decreasing the supply of soil oxygen to plant roots, heavy rainfall or irrigation on such soils can constrain yields to well below their potential (***Poysa et al., 1987***).

Subsurface drip irrigation significantly affects corn yields, which increased with irrigation up to a point where irrigation becomes excessive. Water use efficiency (WUE) increases non-linearly with seasonal ET_c and with yield. WUE is more sensitive to irrigation during the drier season. Irrigation water use efficiency (IWUE) is decreases sharply with irrigation. Irrigation significantly affects dry matter production and partitioning into the different plant components (grain, cob, and stover) (***Payero et al., 2008***).

Plant roots require adequate oxygen for root respiration as well as for sound metabolic function of the root and the whole plant. SDI minimizes alternate wetting and drying of the soil surface, a phenomenon that might otherwise predispose them to the cracking that could locally alleviate the lack of aeration. By direct injection of air alone, by irrigation of a crop with aerated water, aeration of the crop root zone can now become a reality (***Bhattarai et al., 2004***). Injection of air alone is expensive and the injected air moves away from the root zone due to the chimney effect (***Goorahoo et al., 2002***).

The oxygenation is the delivery of aerated water by way of SDI systems. Aerated through a venturi principle, or with solutions of hydrogen peroxide, SDI provided yield benefits to a range of crops including cotton, zucchini and vegetable soybean. The reported studies on irrigation so far fail to offer an option for substantial reduction in water use while maintaining crop production, in a recent report on glasshouse and field experiments. ***Bhattarai et al. (2004)*** confirmed that dramatic increases in crop yields, water use efficiency and salinity tolerance could be achieved with the use of oxygenated subsurface drip irrigation water, especially for crops grown on heavy clay soils. The research by ***Bhattarai et al. (2004)*** showed that for soybean, oxygation increased water use efficiency (WUE) (yield divided by seasonal ET) by 54 and 70%, respectively, for hydrogen peroxide application and air injection using a venturi valve, and pod yield by 82 and 96%, respectively, for the two treatments. Likewise, for crops grown across a range of saline soil conditions, aeration using the venturi principle resulted in yields superior to those of the non-aerated controls (***Ninghu and Midmore, 2005***). Benefits of aeration using the venturi principle in California (***Goorahoo et al., 2002***), or using hydrogen peroxide in Germany (***Heuberger et al., 2001***) on crop growth are also reported.

Aeration of subsurface drip irrigation water, using appropriate techniques such as the venturi principle, hydrogen peroxide, or even a twin vortex system, could be potentially the most significant recent approach to economize on large-scale water usage and minimize drainage in irrigated agriculture (***Bhattarai et al., 2006***).

The aim of this study is to evaluate the technical feasibility of injection of ambient air into a subsurface drip irrigation system. Where, it is as a best management practice for crop production and ideally, test technology on Corn (*Zea mays L.*).

MATERIALS AND METHODS

An open field experiment was carried out through installing an irrigation system that combines subsurface drip irrigation (SDI) tape and an air injection system that mixes air with the water delivered within the root zone.

2.1. Location, soil and crop details

The experiment was carried out at experimental station of Cairo University, Faculty of Agriculture, Agricultural Engineering Department, El-Giza governorate, Egypt (latitude 30.0861 N, and longitude 31.2122 E, and mean altitude 70 m). The corn variety was Hybrid single 10 and it was sown on 22 April on both growing seasons 2010 and 2011.

The climate condition of the experimental site has an arid climate with cool winters and hot dry summers. Table (1) summarizes the monthly mean climatic data for both growing seasons 2010 and 2011 for El-Giza city. The soil of experimental site is classified as sandy clay loam (SCL). Some physical and chemical properties of the experimental soil are given in Table (2). Irrigation water has been obtained from a deep well located in the experimental area, with pH 7.2, and an average electrical conductivity of 0.83 dS m^{-1}.

Table 1. Monthly and growing season climatic data of the experimental area

Months	Mean temperatures (°C)						Relative humidity (%)	Sun Shine (hour)
	Minimum		Maximum		Average			
	2010	2011	2010	2011	2010	2011		
April	16.00	10.87	29.60	31.70	23.10	21.29	50	12.80
May	19.20	14.29	33.90	34.40	26.50	24.35	47	13.50
June	22.70	18.93	37.00	36.50	30.00	27.72	52	13.90
July	23.20	21.81	38.20	39.32	30.70	30.57	56	14.30

Table 2. Some physical and chemical properties of the experimental soil

Soil depth (cm)	Texture	FC (cm^3 cm^{-3})	WP (cm^3 cm^{-3})	Bulk density (g cm^{-3})	pH	ECe (dS m^{-1})
0 – 20	SCL	42.07	14.43	1.29	7.74	2.43
20 – 40	SCL	41.80	14.91	1.31	7.69	1.92
40 – 60	SCL	38.96	17.15	1.33	7.81	1.78

Subsurface laterals were placed 20 cm from the soil surface in a trench prepared with a mounted trencher. Then the trenches were carefully backfilled with the previously removed soil. The lateral was 16 mm in external diameter and 60 m long; the emitter type was self compensative. The laterals were replicated three times in the experiment. The emitter features were: 3.85 l h^{-1} flow rate, 30 cm spacing, turbulent flow, completely flow regulated with outstanding clogging resistance, the working pressure was 100 kPa, built-in no-drain device which prevents water draining from drip line when water has been shut off. Plants were spaced 30 cm × 60 cm within and between rows respectively.

Daily soil water balance and crop evapotranspiration (ET_c) were estimated with a computer software CropWat program. The inputs to the program were daily weather data, including rainfall, irrigation date and amounts, initial water content in the soil profile at crop emergence, and crop and site-specific information such as planting date, maturity date, soil parameters, maximum rooting depth, etc. The CropWat program calculated daily ETc This procedure obtains ET_c as the product of the evapotranspiration of a grass reference crop (ET_o) and a crop coefficient (K_c). ET_o is calculated using the weather data as input to the Penman–Monteith equation and the K_c is used to adjust the estimated ET_o for the reference crop to that of other crops at different growth stages and growing environments.

2.2. Air injection

An air compressor and an air volume meter were used as air-injector unit. They were installed in-line immediately after a gate valve. The air volume meter consists of a 1 m length pipe with a diameter of 2 inches, and is used to transform the flow from turbulent to laminar. An air velocity sensor is installed in the centre of the pipe and is used to measure the average velocity (Fig. 1). This way can control the amount of air injected into the irrigation line (12% air by volume of water). Aerated water was delivered to the soil

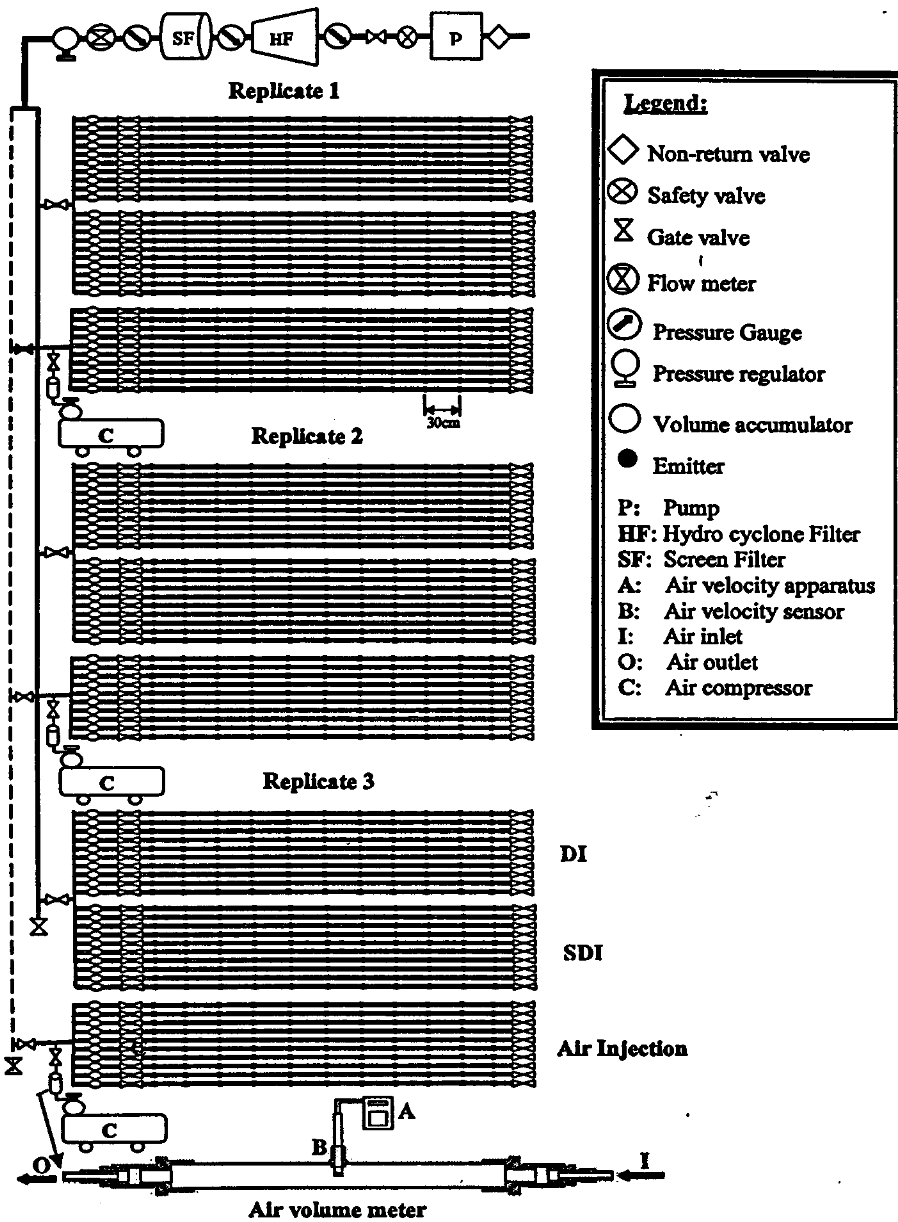

Figure 1. Hydraulic diagram of the microirrigation system, air injection unit, and treatments

through drippers. The water flow was decreased when air was injected and then the time of irrigation was increased to compensate the decrement of water flow. The irrigation time was 30 min and the time of air injection was 3.6 min.

2.3. Soil moisture monitoring

Soil water was measured daily using a profile probe calibrated by using the gravimetric method. The TDR Profile Probe consists of a sealed polycarbonate rod (≈ 25mm diameter), with electronic sensors (seen as pairs of stainless steel rings) arranged at fixed intervals along its length (10, 20, 30, 40, 60 and 100 cm). Irrigation was carried out on a 1–3 day interval, between 7:00 am and 12:00 am, based on the readings from the TDR. A field calibration was made for the profile probe with field measurements along all depths by using the gravimetric method.

2.4. Experimental design and treatments

The experiment laid out with Corn grown at field capacity with and without aeration, three treatments applied, surface drip irrigation (DI), subsurface drip irrigation (SDI) and subsurface with air injection. The area for each treatments is 6 × 60 m. Soil moisture was measured 5 cm away from the emitter by using TDR sensor, water content was periodically verified gravimetrically. Soil moisture was maintained between the refill point (28 %) and field capacity (41 %) as an average value of the three soil layers.

The nutrient requirement of the crop in both experiments was supplied through fertigation using piston pump power by the water pressure system. Fertilizers was consisting of 200 kg ha^{-1} actual N, 50 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O. Starter fertilizer (10-50-10) was applied with the transplant water (500 g in 200 L water and approximately 116 ml of solution per plant).

2.5. Data recording

Weather data was recorded from an adjacent weather station. To measure soil moisture content soil probes were located at 15 cm depth from the soil surface in all treatments with and without aeration. The center three rows of each plot were harvested, the grain yield per plot was calculated in a "wet-mass basis" (standard water content of 15.5%). Eight plants from each plot were also hand-harvested to determine growth and development parameters such as plant height, leaf area and stem diameter, and reproductive parameters such as days to flowering, grain filling, etc. The data for leaf area, stem, and roots was derived from final plant harvest.

Water-use efficiency (WUE) and irrigation water-use efficiency (IWUE) values were calculated were calculated with Eqs. (1) and (2) (***Howell et al., 1990***).

$$\text{WUE} = \left(\frac{E_y}{E_t}\right) \times 100 \qquad (1)$$

Where: WUE is the water use efficiency (t ha^{-1} mm); E_y is the economical yield (t ha^{-1}); E_t is the plant water consumption, mm.

$$\text{IWUE} = \left(\frac{E_y}{I_r}\right) \times 100 \qquad (2)$$

Where: IWUE is the irrigation water use efficiency (t ha-1 mm), E_y is the economical yield (t ha^{-1}), I_r is the amount of applied irrigation water (mm).

2.6. Evaluation Parameters

The emitters were evaluated to see how evenly the water will distributed under air injection using coefficient of manufacturing variation (C_V), by measuring the discharge of a random sample of 20 emitters under different operating pressures (0.75, 1, and 2 kPa) using the following equations:

$$C_v = \frac{S}{\bar{X}} \qquad (3)$$

$$S = \left[\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}\right]^{0.5} \qquad (4)$$

Where:

Xi = the discharge of an emitter.

$\bar{X}$ = the mean discharge of emitters in the sample.

S = the standard deviation of the discharge of the emitters in the sample and n is the number of emitters in the sample (***ASABE Standards, 2002***).

According to the recommended classification of manufacturer's coefficient of variation (C_V) and according to ***ASABE Standards (2002)***, the drippers were classified as excellent ones. The CV was 0.03 under 100 kPa operating pressure, which represents the nominal pressure for the used emitters.

The second parameter of evaluation is the water distribution uniformity. It was conducted through the catch cans test immediately after installation of irrigation system and it was repeated monthly through the growing season to check the distribution uniformity. It was performed in three replicates to evaluate how evenly water is distributed on the soil surface. Twenty cans were used to perform this test and were distributed randomly in the area under study. Using a stopwatch, the water discharged from each dripper in a period of 15 minutes was caught inside the can and the volume of water caught was measured. The discharge in l/h for each dripper was calculated. The distribution uniformity of low quarter was calculated according to ***Burt et al. (1997)***.

$$DU_{lq} = \frac{d_{lq}}{d_{avg}} \qquad (5)$$

Where:

DU_{lq} = distribution uniformity low quarter.

d_{lq} = the lowest quarter depth (lowest 25% of the observed depths).

d_{avg} = the average depth of the total elements (cans). The average of the DU_{lq} for the three replicates was 95.61% under 100 kpa.

2.7. Soil penetration resistance

Penetration resistance was measured by nine insertions in each plot before planting, after that it was measured each two weeks through the growing seasons. It was conducted using a handheld cone penetrometer (Eijkelkamp – Agrisearch Equipment, Netherlands). A penetrologger was used with 11.28 mm cone diameter, 30 degree angle and with vertical speed that doesn't exceed 5 mm s^{-1} based on ASAE standard (*ASAE, 1999*). Penetrometer measurements were taken in increments of 0 to 50 cm depth, 5 cm from dripper and at optimum moisture content.

2.8. Statistical Analyses

Statistical analyses were carried out using the GLM (General Linear Model) procedure of the SPSS statistical package. The model was used for analyzing growth characteristic, WUE, and IWUE as fixed effects on the irrigation treatment and the growing seasons and the double interactions between them, and the replications as error term (***Snedecor and Cochran 1976***).

RESULTS AND DISCUSSIONS

It has been observed that the plant population for year 2010 were approximately the same (55556 plants ha^{-1}) because a planter was used and the rate of seeding was adjusted accurately. The crop was developed at the same spaces each year. The first irrigation was applied approximately at 22 April of each year. The total irrigation water applied each year is shown in Table (3). In 2010 and 2011, water was applied to system maintenance at the beginning of the irrigation period. The system maintenance was conducted prior to planting. No rainfall was recorded on both growing seasons 2010 and 2011, and the irrigation water was applied in 2010 and 2011during the April–July growing season.

The WUE did not differ significantly between the two growing seasons but it differed significantly between treatments, the WUE was significantly higher for Air injection treatment compared with the DI and SDI (Table 3), the IWUE followed the same trend.

The cumulative water applied throughout the growing seasons was greater for DI "12970.15 m^3 ha^{-1}" compared to the SDI and Air injection. The Air injection had the lower cumulative applied water "11502.49 m^3 ha^{-1}". The WUE and IWUE on 2010 were less than 2011 (Table 3). The air injection treatment had the highest WUE and IWUE on both growing seasons, where it was 1.442 and 1.096 kg m^{-3} on 2010 and 1.463 and 1.112 kg m^{-3} on 2011 for WUE and IWUE, respectively comparing with DI treatment that had the lowest values 0.928 and 0.937 kg m^{-3} on 2010 and 0.705 and 0.712 kg m^{-3} on 2011 for WUE and IWUE, respectively (Table 3).

Table 3. Yield, seasonal irrigation, water use, water use efficiency and irrigation water use efficiency of corn under different treatments for two growing seasons

Treatments	Growing season	Seasonal irrigation (m^3ha^{-1})	Water use (m^3 ha^{-1})	Yield (kg ha^{-1})	WUE (kg m^{-3})	IWUE (kg m^{-3})
DI	2010	9857.23 a	12970.15 a	9148.29 c	0.928 c	0.705 c
SDI		9368.72 b	12327.36 b	11226.25 b	1.198 b	0.911 b
Air injection		8741.82 c	11502.49 c	12604.76 a	1.442 a	1.096 a
DI	2011	9906.52 a	13035.00 a	9285.51 c	0.937 c	0.712 c
SDI		9415.56 b	12389.00 b	11428.32 b	1.214 b	0.922 b
Air injection		8785.53 c	11560.00 c	12856.86 a	1.463 a	1.112 a

The soil moisture effect on weight per ear was not significant. Ear dry yield per plant did not differ significantly in response to soil moisture but aeration increased ear dry yield and length compared to the DI and SDI (Fig.2).

The yield was significantly greater for aeration compared to DI and SDI (Table 3). The yield of aerated treatment was higher than DI and SDI by 37.78% and 12.27% on 2010 and 38.46% and 12.5% on 2011.

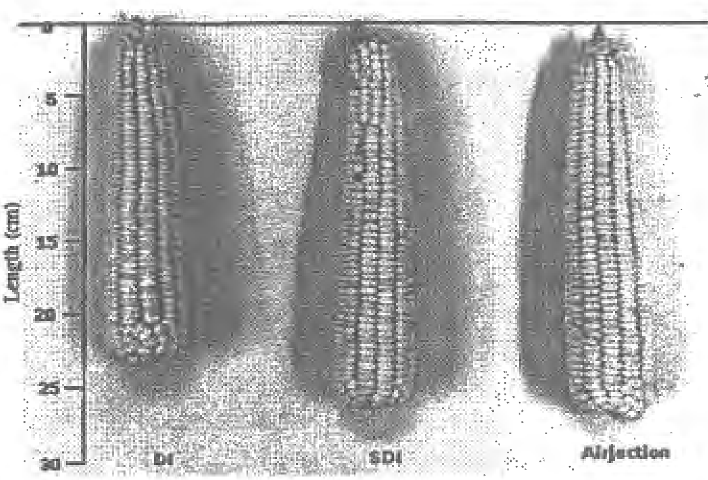

Figure 2. The ear length for different treatments

The effect of aeration and soil moisture was not significant on the number of ears per plant, the individual grains weight per ear were significantly heavier due to aeration compared to DI and SDI 79.8 g ear^{-1} versus 63.7 g ear^{-1} and 74.8 g ear^{-1} on 2010 for DI and SDI, respectively while it was 80 g ear^{-1} versus 65 g ear^{-1} and 75 g ear^{-1} on 2011 for DI and SDI, respectively (Table 4).

Plant height increased with aeration and it was significantly higher than DI and SDI (Table 4). Total leaf area per plant was the lowest at the DI related to the reduction of plant height. Differences in total leaf area per plant and its components were too small to be significant between aeration and SDI (Table 4).

A marked positive effect of aeration was observed on leaf area per plant, primarily because of the larger individual leaves 786.1 cm^2 versus 661 cm^2 and 752.5 cm^2 for DI and SDI, respectively (Table 4). The interaction effect on leaf area was significant, showing a greater positive effect of aeration at field capacity.

Stem diameter had a positive variation in response to aeration, there was a significant difference between air injection and both DI and SDI treatments, the air injection had the highest stem diameter followed by SDI and DI had the least values in both growing seasons 2010 and 2011 (Table 4).

The number of leaves per plant showed significant differences between the aeration treatment and both SDI and DI treatments. However, the length of leaves showed significant differences between the aeration treatment and both DI and SDI treatments. The leaf area per plant was 1.477 and 1.0045 times greater in the aeration treatment than in DI and SDI, respectively (Table 4).

The number of grains per plant was changed under aerated treatment in comparison with DI and SDI (Table 4). Under Air injection treatment, it was increased by 19.4% and 9.9 % on 2010 and 20% and 10.204 % on 2011 when compared with DI and SDI, respectively.

From table (4), the increase in 1000-grain weight for Air injection treatment over the DI treatment was 63.6% for year 2010; and the increase in year 2011 was 65.3%. While the increase in 1000-grain weight for Air injection treatment over the SDI treatment was 7.4% for year 2010; and the increase in year 2011 was 8.3%.

Table 4. Effect of DI, SDI and air injection on some vegetative growth parameters of Hybrid single 10-corn cultivar during 2010 and 2011 seasons

Treatments	Growing season	Total leaf Area per plant (cm^2)	N. of Leaves per plant	Stem diameter (mm)	Plant height (cm)	N. of grains per plant	Grains weight per ear (kg)	1000-grain weight (g)
DI	2010	7312.04 c	9.00 c	22.41 b	259.80 b	532.00 c	0.0637 b	89.87 c
SDI		10754.23 b	12.00 b	23.90 b	264.71b	578.00 b	0.0748 ab	136.87 b
Air injection		10801.99 a	14.00 a	26.89 a	284.31 a	635.00 a	0.0798 a	147.06 a
DI	2011	7348.60 c	11.00 c	22.50 c	265.00 c	540.00 c	0.0650 a	91.10 c
SDI		10808.00 b	14.00 b	24.00 b	270.00 b	588.00 b	0.0750 a	139.10 b
Air injection		10856.00 a	15.00 a	27.00 a	290.00 a	648.00 a	0.0800 a	150.60 a

The aeration had a slight effect on root length and width that it increased the root dimensions in both axes horizontal and vertical related to that when air injected into the water within the root zone, diffusion of ethylene and carbon dioxide away from the roots was increased. This increased diffusion rate should result in improving the growing conditions. The aerated treatment had the highest root length and width, followed by SDI, while the DI treatment had the smallest root dimensions (Fig. 3).

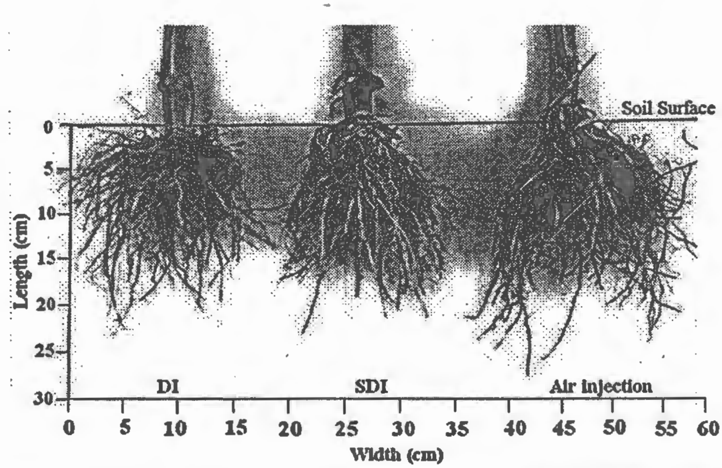

Figure 3. The root shape under different treatments

The maximum values of soil penetration resistance (Cone index) were 2.52 MPa, 2.00 MPa and 1.77 MPa for DI, SDI and Air injection treatments respectively while the minimum values were 0.5 MPa, 0.17 MPa and 0.13 MPa respectively.

Soil penetration resistance differed among DI, SDI and Air injection treatments, Fig. 4 represents an average values for soil penetration resistance through the growing season under DI, SDI and Air injection treatments. These values are the average value for the different measurements of the soil penetration at different times through both. The soil penetration resistance for aerated treatment was lower than DI and SDI treatments this is related to that plant roots require adequate oxygen for root respiration as well as for sound metabolic function of the root and the whole plant. Because of the delicate nature of DI and SDI lines, cultivation does not take place to their depth, therefore predisposing the soil around the lines to compaction. DI and SDI minimize alternate wetting and drying of the soil surface, a phenomenon that might otherwise predispose them to the cracking that could locally alleviate the lack of aeration resulted in soil compaction that increase soil penetration resistance.

Regarding to the plant take off force (the force needed to remove plants from the soil) (Fig. 5), the maximum value 98.7 kg was obtained under DI and the lowest value was 53.2 kg under air injection. The plant take off force decreased with Air injection by about 79.88% and 21.61% comparing with DI and SDI, respectively. The pervious results showed that under air injection the adhesion force between the root and soil is low, also the cohesion force between the soil particles is low, so the take off force for plant is reduced with air injection treatment.

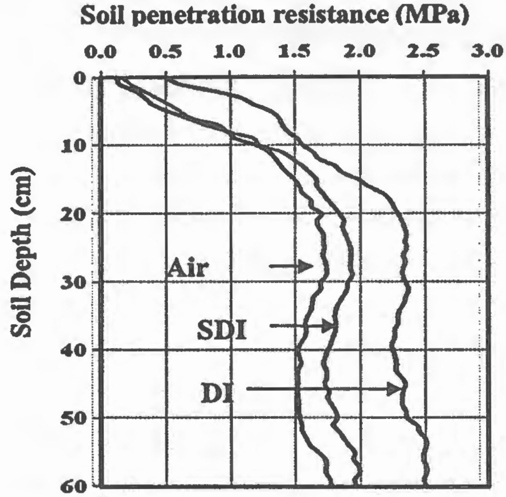

Figure 4. Relationship between penetration resistance and different irrigation treatment

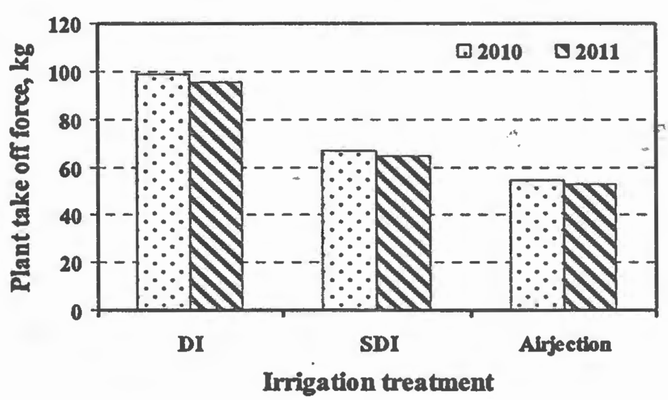

Figure 5. The plants take off force under different treatments

CONCLUSION

Air injection irrigation systems can increase root zone aeration and add value to grower investments in SDI. The increase in yields and potential improvement in soil quality associated with the root zone aeration implies that the adoption of the SDI-air injection technology primarily as tool for increasing corn productivity.

Corn production under aeration conditions is possible if adequate aeration of the soil is provided. The available indigenous materials can be used for aeration in different soil types and conditions in order to reduce the cost of corn production. The cultivation technique developed in this study can be applied to other vegetable and field crops as well as corn and can be utilized even in wet lowlands in delta that have been considered to be wastelands.

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الملخص العربي

تأثير حقن الهواء تحت نظام الري بالتنقيط التحت السطحي على إنتاجية وكفاءة استخدام المياه للذرة الشامية في التربة الرملية الطينية الطميية

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يمكن بإستخدام نظام ألري بالتنقيط التحت سطحي خفض كمية مياه الري المطلوبة لأنتاج الذرة الشامية وتحسين أنتاجية الذرة والتي تعوض التكاليف الأولية لإنشاء نظام الري بالتنقيط التحت سطحي. نظامَ حقن الهواء في التربة قابل للتطبيقُ تحت نظام الري بالتنقيط التحت سطحي، وعليه حجم الهواء المؤثر على حجم التربةِ يكون محدد بظاهرة عمود المدخنة (Chimney column) والذي يقع مباشرة فوق مخرج النقاط. تم إجراء تجربة حقلية خلال موسمي ٢٠١٠ و ٢٠١١ لتقييم إمكانية حقن الهواء في التربة من خلال نظام الري بالتنقيط التحت سطحي وتأثير ذلك على أداء محصول الذرة الشامية. تم أستخدام ثلاث معاملات هي ري بالتنقيط سطحي، ري بالتنقيط تحت سطحي وري بالتنقيط تحت سطحي مع حقن الهواء مع أستخدام ثلاث مكررات لكل معاملة. أوضحت النتائج أن مساحة الورقة كانت أكبر بمقدار ١.٤٧٧ و ١.٠٠٤٥ تحت معاملة الري بالتنقيط تحت سطحي مع حقن الهواء مقارنة بكل من الري بالتنقيط السطحي والتحت سطحي على التوالي. أمتلاء الكوز كان أسرع ووصل إلى حجمه النهائي مبكراً تحت معاملة حقن الهواء مقارنة بكلا المعاملتين الأخريين. أنتشار الجذور، قطر الساق، أرتفاع النبات و عدد الحبوب للنبات الواحد كانت أكبر تحت معاملة حقن الهواء مقارنة بالري بالتنقيط السطحي والتحت سطحي. تم الحصول على أعلى قيمة لكفاءة أستخدام المياه (WUE) وكفاءة أستخدام مياه الري (IWUE) تحت معاملة حقن الهواء مقارنة بنظام الري بالتنقيط السطحي والتحت سطحي خلال كلا موسمي النمو وهي ١.٤٤٢ كجم/م٣ و ١.٠٩٦ كجم/م٣ خلال موسم ٢٠١٠ و ١.٤٦٣ كجم/م٣ و ١.١١٢ كجم/م٣ خلال موسم ٢٠١١ على التوالي. حققت معاملة حقن الهواء أعلى أنتاجية خلال كلا موسمي النمو مقارنة بالري بالتنقيط السطحي والتحت سطحي على التوالي حيث وصلت الزيادة في الأنتاجية خلال موسم ٢٠١٠ إلى ٣٧.٧٨% و١٢.٢٧% بينما في موسم ٢٠١١ كانت ٣٨.٤٦% و ١٢.٥٠%. وعموماً فقد أوضحت الدراسة فعالية تطبيق حقن الهواء بإستخدام نظام الري بالتنقيط التحت سطحي لما له من تأثير إيجابي على زيادة كل من الأنتاجية، كفاءة أستخدام المياه وكفاءة أستخدام مياه الري. وقد أوصت الدراسة بالتوسع في أستخدام تقنية حقن الهواء مع محاصيل لخرى وتحت أنواع مختلفة من الأراضي خصوصاً الأراضي الطينية التي تروي بنظام الري بالغمرلما له من مزايا تتعلق بتحسين بيئة أنتشار الجذور وتهوية التربة.

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