Effect of Furrow Cross Section on Water Use Efficiency of Corn and Yield

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Abstract

The experiment was conducted to evaluate the effect furrow cross section and water use efficiency for corn crop and yield during the summer growing season of 2013 in the experimental at fields of Faculty Agricultural University of Baghdad in silt clay soil. The experimental treatments were split plot arranged in Randomize Complete Block Design with three replicates. The main plots were assigned to speeds of the tractor (4.23, 6.27 and11.17 km h^{-1}), whereas depth of furrows was assigned to the sub plots (15, 20 and 25 cm). Grains of corn (synthetic cv. Maize 5018) were sowing was done on August 18th; harvest was done on December 10th. Irrigation were scheduled when soil water content in the root zone was depleted by the crop to specific fraction of available water (irrigation was imposed at 55% depletion of available water). Technical performance indicators for the unit machine (furrow width) measured by ruler measure length of 1 m. At harvest time, two central rows in each plot were harvested to determining grain yield and then; grain yield per hectare was calculated, and irrigation Water Use Efficiency (WUE_{IR}).
The results showed that furrow width increased with increase speed operation and recorder 68.74, 77.0 and 82.81 cm for 4.23, 6.27 and 11.17 km. h^{-1}, respectively. While the furrow width recorder 75.03, 76.11 and 77.41 cm for 15, 20 and 25 cm depths of furrow, respectively. Increase speed tractor and depth machine reduce distance between the gore. The amounts of applied water irrigation and cumulative ET_a of different speed tractor and furrow depth treatments during the growth period. Total water supply was 494, 529 and 593 mm for 4.23, 6.27 and 11.17 km h^{-1}, respectively. The ET_a measured during the season was 658, 693 and 757 mm for 4.23, 6.27 and 11.17 km h^{-1}, respectively.

KEYWORD: corn, furrow cross section, speed tractor, Water Use Efficiency, yield.

INTRODUCTION

In dry land agricultural production systems, water is the most limiting factor that is aggravated by high evaporation rates. Crop production and food security can therefore not be maintained without irrigation. Two factors cast a long shadow on the long-term sustainability of irrigation practices. The first one is that the competition for water between agricultural, domestic, and industrial consumers is on the rise while good quality water sources are on the decline (Rosegrant and Ringler, 1999). The second one is that the various models used to predict the effect of global warming on rainfall, and hence on water supplies, indicates that in large parts of semi-arid, dry-sub humid and sub-humid regions rainfall may decrease (Metzger *et al.*, 2005; Black, 2009).
Design furrow cross section is very important. Cahoon (1995) stated that it is useful to define a standard shape that represents the furrow cross section. They discussed five geometric shapes that could be used: (1) linear interpolation between successive points; (2) trapezoid symmetric about the furrow center; (3) a least-squares parabola that only considers portions of the furrow in which flow can occur without overtopping the furrow ridge; (4) a sigmoid

with the period equal to the furrow spacing and amplitude equal to half the maximum depth; and (5) a least-squares fit triangle. The researchers stated that the shape chosen is likely to depend on furrow conditions and the ultimate reason for defining the cross section.

Furrow irrigation is the dominant practice for maize production in the middle and south of Iraq. Moreover, the tendency of farmers in this area to over irrigate results in drainage and salinity problems. Improvement of the existing irrigation system and management techniques is necessary to ensure more efficient water use without significantly reducing maize yield.

Corn (*Zea mays* L.) is the world's third most important cereal after wheat and rice grown primarily for grain and secondarily for fodder (Nelson, 2005). The purposes of this work were to present and discuss improvements to furrow irrigation systems that will result in lower irrigation water use and higher irrigation performance, but that do not require heavy investment and may be easily adopted, through the use of different speeds of the tractor and depth of furrows for the best rate of furrow width.

MATERIAL AND METHODS

Experimental site and climate: The experiment was carried out during spring seasons of 2013 in field of Agricultural Collage- University of Baghdad /Abu-Graib- Baghdad, Iraq (33º 20´ N, 44º 12´ E; elev. 34.1 m). Corn (*Zea mays* L.) was planted on soil of EC_e (3.41 $dS.m^{-1}$), pH (7.52), organic matter (12.13 g kg^{-1}), silt clay texture (Sand=110 g kg^{-1}, Silt=470 g kg^{-1} and Clay = 420 g kg^{-1}) with average bulk density of 1.42 $Mg.m^{-3}$ and soil content moisture 0.332 cm^3cm^{-3} at field capacity and wilting point equal 0.164 cm^3cm^{-3}, soil properties were determined using the standard laboratory methods (Black, 1965 a & b). During the cultivation seasons; the mean relative humidity was 48% and mean rainfall was 164 mm and average wind speed 1.82 ms^{-1} during corn growing season.

Crop management and experimental design: The experimental treatments were split plot arranged in Randomize Complete Block Design with three replicates. The main plots were assigned to speeds of the tractor (New-Holland TD 80 tractors were used), whereas depth of furrows was assigned to the sub plots. Plots area was 3×10 (30 m^2), while leaving distance 10 m before replicate for the purpose acquisition tractor speed estimated in Job, were distributed treatments random. Grains of corn (synthetic cv. Maize 5018) were sown with recommended dose of fertilizer compound (N P) (27-27) with rate 400 kg. ha^{-1}, Recommended rate of nitrogen 400 kg ha^{-1} (46% N) was applied as a form of urea in two split equal doses (at 6 leaves stage, and after 30 days from first applied). Sowing was done on August 18th. Harvest was done on December 10th. All other agricultural practices were carried out as recommended. The treatments were:

1. Speed of tractor treatment was as follow:

a. 4.23 km h^{-1}
b. 6.27 km h^{-1}
c. 11.17 km h^{-1}

2. Depth of furrow treatment was as follow:

a. 15 cm
b. 20 cm
c. 25 cm

All plots were irrigated with river water an ECi = 1.21 $dS.m^{-1}$ and SAR = 1.98 $(mmol\,.L^{-1})^{½}$. Irrigation were scheduled when soil water content in the root zone was depleted by the crop to specific fraction of available water (irrigation was imposed at 55% depletion of available water). The soil depth of the effective root zone is increased from 0.30 m at planting to 0.60 m in flowering and beginning grain stages. Measured amount of water were delivered to the furrows using water meter gages. Soil water content was measured gravimetrically method 1-2 days before and 2-3 days after irrigation. In this study irrigation treatment were analyzed (every-furrow irrigation in which water is always applied to every furrow, uses open-end furrows and is known as the conventional continuous furrow application). Total irrigation time or cut-off time (t_{co}) for these treatments was estimated as in equation 1:

$$t_{co} = T_a + T_i \dots\dots\dots (1)$$

Where t_{co} is the cut-off time (min), *Ta*, is the advance time (min), and *Ti*, is the intake opportunity time for the soil moisture deficit at the lower end of the furrow (min). The average depth of water applied (*D*, mm) for treatments were computed from the following equations 2:

$$D = \frac{q_{in} \times 60 \times t_{co}}{L \times S} \dots\dots\dots (2)$$

Where q_{in} is the inflow rate ($m^3\ min^{-1}$) during an irrigation event, and *L* and *S* are the length and spacing (m) of a furrow, respectively. Actual evapotranspiration values (*ET*, mm) for all treatments were calculated as in equation 3:

$$I + P = ET_a + D + \Delta S \dots\dots\dots (3)$$

Where P is the rainfall (mm); I is the irrigation applied to individual plots (mm); D is the deep percolation; and Δs is the change in water storage of the soil profile (mm). Since the amount of irrigation water was only sufficient to bring the water deficit to field capacity, deep percolation was ignored. Irrigation water use efficiency (WUE_{IR}) was estimated by equation (4) using the model given by Howell *et al.* (1990), which is yield produced per cubic meter of irrigation water.

$$WUE_{IR} = \frac{Y_a}{D} \dots\dots\dots (4)$$

Technical performance indicators for the unit machine (furrow width) measured by ruler measure length of 1 m. At harvest time, two central rows in each plot were harvested to determining grain yield and then; grain yield per hectare was calculated. Analysis of variance (ANOVA) was conducted to evaluate the effects of the treatments on the yield and water use efficiency. Least significant differences method (L.S.D) was used to differentiate means at the 0.05 level (SAS, 2010).

RESULTS AND DISCUSSION

Table 1 shows the significant effect of speed the tractor, depths of furrow and interactions in furrow width. Furrow width increased with increase speed operation and recorder 68.74, 77.0 and 82.81 cm for 4.23, 6.27 and 11.17 km h^{-1}, respectively. While the furrow width recorder 75.03, 76.11 and 77.41 cm for 15, 20 and 25 cm depths of furrow, respectively. May be due the increased speed, increase of the volume of soil (quantitative a cross from the soil) by furrow machine, which leads to an increase in the furrow width, also the results clear the furrow width was appropriate under display recommended for cultivation corn for the first two speeded, but increased speed 11.17 km h^{-1} show not appropriate and cause loss area of farm, while increase the depth machine in the earth, lead to an increase furrow width.

The resulted from treatment increase speed tractor and depth machine reduce distance between the gore (Table 1). This may be due to the increased speed operation increase slipping, and reduced linear distance therefore convergence of distance between the gore. The speed 6.27 km h^{-1} has been given the best distance between the gore (26 cm) recommended by the competent departments of agricultural. While increase furrow depth led to increased resistance drag and then less speed operation, leading to reduce the distance between gore. Therefore, increasing the speed tractor led to reduce the distance between the gore, and increasing the number of gore per hectare and then increase seed quantity per area unit.

Table 1. Effect of speed tractor and depth of furrow on furrow width, distance between gore and seeds rate

Treatment		Furrow Width	Distance Between Gore	Seeds Rate
		cm	cm	kg ha^{-1}
Speed of tractor				
4.23 km. h^{-1}		68.74	46	22.44
6.27 km. h^{-1}		77.00	26	30.60
11.17 km. h^{-1}		82.81	5	54.40
LSD		0.58	2	1.58
Depth of furrow				
15 cm		75.03	29.00	31.31
20 cm		76.11	25.67	35.79
25 cm		77.41	22.33	40.33
LSD		0.41	1	1.12
Speed of tractor × Depth of furrow				
4.23 km. h^{-1}	15 cm	67.33	51	19.08
	20 cm	68.55	46	23.10
	25 cm	70.33	41	25.13
6.27 km. h^{-1}	15 cm	76.00	29	25.46
	20 cm	76.89	26	29.69
	25 cm	78.11	23	36.65
11.17 km. h^{-1}	15 cm	81.77	7	49.40
	20 cm	82.89	5	54.60
	25 cm	83.78	3	59.20
LSD		1.67	3	2.64

Table 2 shows the amounts of applied water irrigation and cumulative ET_a of different speed tractor and furrow depth treatments during the growth period. Total water supply was 494, 529 and 593 mm for 4.23, 6.27 and 11.17 km.h^{-1}, respectively. The ET_a measured during the season was 658, 693 and 757mm for 4.23, 6.27 and 11.17 km h^{-1}, respectively. The amounts of irrigation water increase with increase in speed tractor and furrow depth, this is due to increase the furrow width (Table 1), which reflected on the cross section of furrow. The amounts of irrigation water in 6.27 and 11.17 km h^{-1} treatment were similar to those reported by Al-Hadithi (2002) and Salih and Falih (2012) where experiment carried out in center of Iraq.

Table 2. Factors the water balance for corn crop

Treatment		Number of irrigation	Rainfal	Irrigation Water applied	Actual evapotranspiratio	Yield	WUE_{IR}
			mm			kg ha^{-1}	Kg m^{-3}
4.23 km h^{-1}	15 cm	15	164	475	639	3180	0.67
	20 cm	15	164	491	655	4240	0.86
	25 cm	15	164	516	680	7360	1.43
Mean		15	164	494	658	5020	1.02
6.27 km h^{-1}	15 cm	15	164	507	671	4020	0.79
	20 cm	15	164	525	689	7010	1.34
	25 cm	15	164	555	719	11520	2.08
Mean		15	164	529	693	7150	1.35
11.17 km h^{-1}	15 cm	15	164	554	718	7470	1.35
	20 cm	15	164	585	749	8890	1.51
	25 cm	15	164	640	804	18080	2.82
Mean		15	164	593	757	11480	1.94

Water use efficiency (WUE_{IR}) expressed as the ratio of corn yield to water supply from planting to harvest (Table 2). The highest WUE_{IR} value was obtained from (11.17 km h^{-1} + 25cm) treatment with average of 2.82 kg m^{-3}. But this does not mean get the best efficiency in this treatment, because the treatment used larger quantity of seed (59.2 kg ha^{-1}) and highest amount of water (640mm), as well as cause loss area of farm because increase furrow width (83.78 cm) (Table 1). The best WUE_{IR} value was obtained from (6.27 km h^{-1} + 25cm) treatment, the reason for this treatment has given best produce in contrast a amount of seed used (36.65 kg ha^{-1}), as well as the optimal cross-section which work to optimal amount capacity of water and higher productivity (11520 k ha^{-1}) compared to other treatments. These results are supported by achievement of Sepaskhah and Ghasemi (2008) and Shayannejad and Moharrery (2009) and Masoud and Shakarami (2010).

The results of Table 2 indicate significant differences of speed tractor and depth machine treatment in corn yield recorder 5020, 11480 kg ha^{-1} for 4.23, 6.27 and 11.17 km h^{-1}, respectively. It appear from the results mentioned above different significant between treatment furrow depth (15, 20 and 25 cm) for all speed tractor, this due the increase depth furrow lead to increase furrow width and reached 88.78 cm in (11.17 km h^{-1} + 25cm) (Table 1) treatment became unsuitable for planting corn.

CONCLUSIONS

Through the above results it is clear that increased speed tractor and furrow width led to a increase significant in the furrow width, quantity of seeds, and reduce the distance between the gore, Therefore, we recommend using a (6.27 km h^{-1} + 25cm) treatment which gave the best measurements of furrow which are located within the measurements recommended, as well as give well yield within the amount of seed, which worked on stretch the root system and increase efficiency absorption nutrients and improve the properties of the vegetative growth, the process of photosynthesis and productivity

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