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YIELD AND WATER PRODUCTIVITY OF RICE ON RAISED BEDS, IRRIGATION INTERVALS AND AMMONIA GAS INJECTION AT NORTH NILE DELTA

Mahmoud, M. A.
Soils, Water and Environment Research Institute, ARC, Giza, Egypt

ABSTRACT

Field experiments were conducted in 2014 and 2015 at Sakha Agriculture Research station, Kafr El-Sheikh (31° 07' N Latitude, 30° 57' E Longitude) at North Nile Delta, Egypt to study the effects of raised beds, irrigation intervals and ammonia gas injection levels on water productivity (WP) of rice. A split split plot design with four replications was used. Ammonia gas injection levels were devoted to the main plot, irrigation treatments were allocated in sub-plots and rice planting methods were arranged in sub sub-plots. Ammonia gas injection levels were 70 unit nitrogen N (F_1), 80 units (F_2) and 90 units (F_3). Planting methods treatments were transplanting in flat, as a traditional method (M_1), and transplanting in raised beds only (M_2). Irrigation intervals were irrigation every four days after transplanting (I_1), irrigation every six days after transplanting (I_2), and irrigation every eight days after transplanting (I_3). Results showed there was no significant difference on GY between I_1 and I_2 while there were a significant difference on SY, BiomY and other yield components between I_1, I_2 and I_3. The highest values of SY, BiomY and other yield components were obtained from I_2 compared to I_1 and I_3. As for planting treatments, GY, SY and BiomY increased by 20.8%, 40.4% and 31.7% respectively under M_2 compared with M_1. There were no significant differences on GY and its attributes between F_2 and F_3 except SY and BiomY.

Mean values of water applied for M_1 received the highest amount of IWA to be 14338 m^3 ha^{-1} compared to M_2 which was 10443 m^3 ha^{-1}, respectively. The amount of water used in M_2 is a feasible amount to grow rice with a 27.2% saving of water. Higher value of WP of I_2 proved its superiority over I_1 and I_3 treatments by 16% and 7%, respectively. Planting method treatment M_2 increased NUE by 21% compared to M_1. The highest values of NUE were recorded for I_1 and I_2 without any significant differences between them whereas the lowest one was obtained from I_3. Also, the highest mean value of NUE was obtained under F_1 whereas the lowest was under F_3.

Therefore**,** M_2 could be applied by the farmers' under irrigation interval of I_2 and 80 units N as ammonia gas injection (F_2) because it saved irrigation water by 36% and increased NUE by 17% compared to M_1 x I_1 x F_1 which in normally practiced in North Delta, Egypt, without any reductions in GY.

Keywords: Rice transplanting in beds, ammonia gas injection levels, irrigation intervals applied irrigation water, irrigation water productivity.

Abbreviations: irrigation water applied (IWA), Water productivity (WP), nitrogen use efficiency (NUE), grain yield (GY), straw yield (SY), and biomass yield (Biom Y).

INTRODUCTION

Worldwide, availability of freshwater for irrigation is decreasing because of increasing competition from industrial and urban development, Irrigation infrastructure degradation and water quality degradation (Molden, 2007). Globally, the supply of water is limited and rice is a high water consuming crop, particularly under the traditional irrigation method. Research workers are forced to find ways for saving some of such water without considerable decrease in yield by the remarkable increase in population and the limitation of water resources.

About 60 cm of irrigation water are saved by seedling rice in beds and furrows in comparison with planting seedlings in flat puddles (Devinder *et al.,* 2005). In terms of yield parameters, planting on raised beds was appreciably better than other techniques. As planting on raised bed gave the maximum paddy yield (6.70 t ha^{-1}), followed by drill sowing through a bed planter (6.0 t ha^{-1}), so drill sowing through bed planter and planting on raised beds was considered as the best planting technique regarding yield and yield components of rice (Khattak *et al.,* 2006). It is found that furrow and bed planting saved about 60 cm of irrigation water from transplanting to harvest and about 44 to 50% more WP than traditional plantings (Jagroop *et al.,* 2007). In comparison with the traditional planting methods, planting rice in beds or furrows can extensively increase the productivity of yields and irrigation water. Planting rice in beds increased, the number of tillers /hill, plant height the number of panicles /hill, and panicle length by 21%, 4%, 18% and 6%, respectively, It also increased rice yields by 4%, WP by 66%, and water savings by 38% (Meleha *et al.,* 2008). Transplanting rice in bottom of beds significantly increased grain yield and WP by 3.45% and 58.1 % respectively, while saved IWA by 35.2%. compared with traditional transplanting method (El-Atawy, 2012). Naresh *et al.* (2014) showed that alternate wetting and drying saved a large amount of irrigation water (15%–50%), and wide raised beds saved approximately 15%–24% form irrigation water compared with continuously flooded rice.

Water productivity can be increased and water inputs reduced by using periods of none submerged conditions of several days (Bouman and Tuong, 2001). Grain yield was statistically the same under continuous flooding and 8 days interval however, water consumption decreased 18% under 8 days interval (Ashouri, 2012). Rice grain yield under alternate wetting and drying treatments were comparable with continuous flooding, while under alternate wetting and drying treatments IWA was significantly reduced. There were no significant differences in grain yield among alternate wetting and drying, continuous flooding and conventional farmer's practice. IWA under alternate wetting and drying treatments was 19.4% to 29.7% lower, and WP was 31.7–53.2% higher than conventional farmer's practice in South China (Liang et al., 2016).

In the last half of century, rice yield in the world has rapidly increased, partly because of the increase in fertilizer nutrient input, especially nitrogen (N) fertilizer (Cassman *et al.,* 2003, Peng *et al.,* 2010). Nitrogen, among nutrients, is the most important and the most limiting element in rice growth (Haefele *et al.,* 2006). However, the use of N fertilizer is generally inefficient, and the apparent recovery efficiency of N fertilizer (the percentage of fertilizer N recovered in aboveground plant biomass at the end of the cropping season) is only 33%, on average (Raun and Johnson,1999; Garnett *et al.,* 2009). The high N input and low NUE could not only increase the production cost, but also result in severe environmental pollution (Ju *et al.,* 2009; Peng *et al.,* 2009 Guo *et al.,* 2010; Chen *et al.,* 2014). Water and nitrogen (N) are considered the most important factors affecting rice production (Ya-Juan *et al*., 2012). Grain, straw yields and yield attributes viz, productive tillers, grain per panicle, panicle length, and test weight were effectively increased with fertilizer N application (Vennila *et al.,* 2007).With the increase in nitrogen application level, nitrogen accumulation in plants and rice production increased, but nitrogen-use efficiency decreased (Zhong-cheng *et al.,* 2012). The panicle number, panicle dry matter, panicle length, number of primary branches, total grain and grain yield are observed to increase with nitrogen fertilizer increase. (Yoseftabar, 2013).

The objective of this study was to investigate the effects of raised beds, irrigation intervals and ammonia gas injection levels on enhancing irrigation water productivity and rice yield.

MATERIALS AND METHODS

Experimental site

Rice field experiments were conducted in 2014 and 2015 summer season at Sakha Agriculture Research Station, Kafr El-Sheikh Governorate, North Delta of Egypt. The site allocated at 31° 07' N Latitude, 30° 57' E Longitude with an elevation of about 6 meters above mean sea level. The soil at the experimental site is clayey in texture (53.6 clay, 26.3 silt, 20.1% sand). The average soil electrical conductivity (EC) in the saturated soil paste extract, over 0-60 cm depth, was 2.27 dS m^{-1}. The EC of the irrigation water was 0.45 dS m^{-1}. The previous crops were clover and wheat in the 1^{st} and 2^{nd} year seasons, respectively.

Weather data for the experimental site, during 2014 and 2015 seasons, were obtained from Sakha agro-meteorological station. Monthly mean values of air temperature, relative humidity, wind speed, solar radiation, and pan evaporation are presented in Table (1), and the mean values of some soil physical, chemical properties and some water constants of the experimental site before cultivation were presented in Table (2).

Table (1): Sakha agro-meteorological data, (31° 07' N Latitude, 30° 05' E Longitude), during 2009 and 2010 seasons.

Seasons	Months	Air temperature			Relative humidity			Wind speed	Solar radiation	Pan evaporation
		Max. °C	Min. °C	Mean °C	Max. %	Min. %	Mean %	Mean km d^{-1}	Mean MJm^{-2} d^{-1}	Mean mm d^{-1}
2014	May	30.47	19.57	25.02	77.20	48.60	62.90	98.86	26.2	5.9
	June	32.65	20.6	26.63	86.23	52.30	69.27	82.3	27.2	6.6
	July	33.15	23.64	28.40	83.19	55.11	69.15	97.90	27.7	7.7
	Aug.	34.10	21.80	27.95	92.40	53.50	72.95	99.03	25.8	8.1
	Sept.	32.49	20.76	26.63	87.57	52.20	69.89	89.17	22.7	6.6
	Oct.	29.75	18.75	24.25	80.92	53.39	67.16	81.83	18.1	4.5
2015	May	30.90	18.79	24.49	77.30	46.10	61.70	114.60	26.2	7.1
	June	30.85	21.40	26.13	78.80	51.20	65.00	105.30	27.2	6.9
	July	33.00	22.40	27.70	85.20	54.30	69.75	97.30	27.7	6.9
	Aug.	335.10	25.00	30.05	83.80	51.70	67.75	91.20	25.8	8.1
	Sept.	34.60	23.80	29.20	82.70	46.50	64.60	98.30	22.7	6.6
	Oct.	29.90	20.60	25.25	80.90	54.10	67.50	87.00	18.1	4.5

Table (2): Mean values of some soil physical, chemical properties and some water constants of the experimental site before cultivation.

Depth cm	Particle Size Distribution %			Texture class	Bulk Density Mg/m^3	Field Capacity %	Permanent wilting point %	Available Water %	pH	Ec dsm^{-1}
	Sand	Silt	Clay							
0 - 15	19.40	27.40	53.20	Clayey	1.21	45.60	24.20	21.40	8.05	1.86
15- 30	20.10	26.00	53.80	Clayey	1.26	39.50	22.30	17.20	8.15	2.09
30- 45	20.80	25.10	54.20	Clayey	1.35	38.00	21.20	16.90	8.22	2.28
45- 60	20.20	26.70	53.10	Clayey	1.24	40.10	22.10	18.00	8.39	2.86

Experimental design and treatments:

The experiment was set up as split split-plot design with four replications. Ammonia gas injection levels treatments were in the main plot, irrigation treatments were allocated in sub-plots and rice planting methods were in sub sub-plots. Ammonia fertilizer levels were 70 unit nitrogen (N), 80 unit N and 90 unit N. Planting treatments were: traditional transplanting in flat, flooded soil as a traditional method (M_1), transplanting in raised beds only (M_2). Irrigation intervals were: irrigation every four days after transplanting (I_1), irrigation every six days after transplanting (I_2) and irrigation every eight days after transplanting (I_3). The plots were isolated by ditches of 2.5 m in width to avoid lateral movement of water. At irrigating, plots were submerged to a depth of 7 cm for M_1 and 7 cm at the bottom of beds.

The applied irrigation water to each experimental plot was measured using spile tubes, two spiles of 7.5 cm inner diameter PVC tubes and 80 cm length were used to let water from field ditches into each plot. The effective head of water above the cross section center of irrigation spile was measured several times during irrigation and the average value was 10 cm .The water in the canal of the field was controlled to maintain a constant head by means of fixed sliding type gates. Stage gauges were placed in each plot to measure the depth of water flowing through the spile. The amount of water in each application was added until it reaches the required submerged depth (7 cm), and the time of the water applied was monitored using a stop watch.

The amount of water delivered through the spile tube was calculated according to Majumdar (2002) by the equation;

$$q=CA\sqrt{2gh} \quad (1)$$

Where: q = Discharge of irrigation water (cm^3/s),
C = Coefficient of discharge = 0.62 (determined by experiment),
A = Inner cross section area of the irrigation spile (cm^2),
G = Gravity acceleration (cm/s^2) and
H = Average effective head (cm).

The volume of water delivered for each plot (6m×7m = 42 m^2) was calculated by substituting Q in the following equation:

$$Q= q \times T \times n \quad (2)$$

Where : Q = volume of water m^3/ plot,
q = discharge (m^3/min),
T = total irrigation time (min) and
n = number of spiles tube per each plot.

Seedlings of rice cv. Sakha 179 were transplanted on the 15th of Mayin 2014 and 19th of may in 2015. Twenty-five days old seedlings were transplanted in hills spaced 20 X 20 cm for M_1 and 10 X 40 cm in the two rows at the bottom of beds for M_2. All treatments had 25 hills m^{-2}. Cultural practices were similar to those used in the area. Rice plants were harvested after 122 days from seeding.

The collected data

Data collected were plant height, number of tillers/ hill, plant height, weight of 1000 grain weight, panicle length, GY, SY and BiomY at maturity. Data on plant height, number of tillers/ hill, weight of 1000 grain and panicle length were taken on ten randomly selected guarded hills from the central four rows in M_1 and from the fourth bed in M_2 for each plot. Rice GY, SY and Biom Y were obtained from the central area of each treatment to avoid any border effect. Plot size was 42 m^2 (6m ×7m) and GY, SY, and Bioms Y were harvested from 20 m^2. Grain yield was calculated based on the adjustment to grain moisture content of 140 g kg^{-1}. Biomass yield includes grain and straw yield.

Harvest index (HI) = $\dfrac{\text{Grain yield in kg ha}^{-1}}{\text{Biomass yield in kg ha}^{-1}}$

Water productivity (WP)

The Productivity of irrigation water in kg grain m^3 was calculated according to Ghane *et al.* (2010) and Ali *et al. (*2007), as follows:

WP = $\dfrac{\text{Grain yield in kg ha}^{-1}}{\text{Amount of applied water in } m^3 \text{ ha}^{-1}}$

Nitrogen utilization efficiency (NUE):

It determines the forage yield produced by one kg of added nitrogen and calculated according to Sisworo *et al.* (1990) as follows:

$$\text{NUE} = \frac{\text{Yield fertilized N - yield control N, kg}}{\text{N. applied}}$$

The statistical analysis

Statistical analysis of variance (ANOVA), as well as the correlation coefficient and regression were performed using CoStat software. The data for the two years were combined. Treatment means were compared using Duncan's multiple range test which was statistically significant when $P \leq 0.05$

RESULTS AND DISCUSSION

Grain yield and its attributes:

Results in Table (3) show that there were a significant increase in GY, SY, BiomY, number of tiller/hill, panicle height and weight of1000 grain for M_2 compared with M_1, however harvest index and plant height were highly significant under M_1 compared with M_2. Grain yield, straw yield and biomass yield increased by 20.8%, 40.4% and 31.7% under M_2 compared with M_1 respectively. These results coincided with those obtained by Atta (2005), Atta *et al.* (2006), Khattak *et al.* (2006), Mishra and Saha (2007), and Jagroop *et al.* (2007), and El-Atawy (2012) they found that rice transplanted in beds produced significantly high GY. There was no significant difference on GY between I_1 and I_2.while there were a significant difference on SY, BiomY and other yield components between I_1, I_2 and I_3. the highest values were obtained under I_2 compared I_1 and I_3 except harvest index was highly significant under I_1 compared to I_2 and I_3 (Table 2). these results agree with Ashouri (2012) who reported that Grain yield was statistically the same under continuous submergence and 8 days interval.

Table (3): Average values of grain yield, straw yield, biomass yield, harvest index, number of tillers/hill, plant height, panicle length and weight of 1000 grain as influenced by planting methods irrigation intervals and ammonia levels in combined analysis of 2014 and 2015 seasons.

Treatments	Grain Yield (t ha-1)	Straw Yield (t ha-1)	Biomass yield (t ha-1)	Harvest index	Number of tiller/hill	Plant height, cm	Panicle length, cm	Weight of 1000 grain
Methods of planting								
M_1	9.43 b	11.92 b	21.36 b	0.44 a	25.59 b	83.82 a	19.54 b	20.36 b
M_2	11.39 a	16.74 a	28.13 a	0.41 b	25.96 a	83.24 b	20.72 a	20.41 a
Irrigation								
I_1	10.92 a	13.98 b	24.90 b	0.44 a	25.44 b	82.94 b	20.23 b	20.39 b
I_2	11.01 a	15.41 a	26.42 a	0.42 b	27.39 a	84.96 a	20.54 a	20.44 a
I_3	9.31 b	13.61 c	22.92 c	0.41 b	24.5 c	82.69 c	19.62 c	20.32 c
Ammonia levels								
F_1	9.89 b	13.72 b	23.61 c	0.42 ab	24.5 b	82.34 b	18.9 b	20.33 b
F_2	10.59 a	14.01 b	24.61 b	0.43 a	26.33 a	84.47 a	20.17 ab	20.35 ab
F_3	10.74 a	15.27 a	26.01 a	0.41 b	26.5 a	83.78 ab	21.33 a	20.47 a
F x I	*	**	**	**	**	**	**	**
M x I	*	**	**	*	**	**	*	**
M x F	*	**	**	*	**	**	**	**
M x F x I	**	**	**	**	**	**	*	**
M x F x I x year	ns	ns	ns	ns	ns	ns	ns	ns

Means designed by the same letter at each cell are not significantly different at the 5% level according to Duncan's multiple range test n.s: Indicate not significant.

There were no significant differences on GY and its attributes between F_2 and F_3 except SY and Biom Y. Harvest index was higher in F_2 than F_3. The lowest values were obtained from F_1 except under harvest index (Table 3). These result agree with Zhong-cheng *et al.* (2012) and Yoseftabar (2013).

There was no significant interaction between planting methods x ammonia x irrigation x year for all traits (Table 3). The interaction between ammonia x irrigation, planting methods x irrigation, planting methods x ammonia and planting methods x ammonia x irrigation were significant on GY and its attributes.

Data in Table (4) shows that the average values of GY, SY, Biom Y, harvest index, number of tillers/hill, plant height, panicle length and weight of 1000 grains were significantly affected by the interaction between irrigation intervals x ammonia levels, irrigation intervals x planting methods and ammonia levels x planting methods, over both seasons. It is obvious form Table 3 that the highest mean values of GY was under I_1x F_2, I_1 x F_3, I_2 x F_2 and I_2 x F_3 without any significant differences between them. Also, the highest mean values of SY, Biom Y, number of tillers/hill, panicle length and weight of 1000 grain was under I_2 x F_3 whereas the lowest was under I_3 x F_1. Water and nitrogen (N) are considered the most important factors affecting rice production (Ya-Juan et al. 2012) .

Table (4): The interaction between irrigation intervals x ammonia levels, irrigation intervals x planting methods and ammonia levels x planting methods on rice yield and its components.

Irrigation	F_1	F_2	F_3	M_1	M_2	Ammonia	M_1	M_2
	GY in t ha-1			GY in t ha-1			GY in t ha-1	
I_1	10.23 b	11.15 a	11.39 a	10.02 d	11.82 b	F_1	8.87 e	10.92 b
I_2	10.38 b	11.38 a	11.27 a	9.92 d	12.09 a	F_2	9.50 d	11.69 a
I_3	9.08 d	9.27 cd	9.58 c	8.36 e	10.26 c	F_3	9.93 c	11.56 a
SYt ha-1								
I_1	12.4 d	14.14 c	15.41 b	11.87 d	16.10 b	F_1	11.02 e	16.42 b
I_2	15.88 ab	14.13 c	16.23 a	12.97 c	17.86 a	F_2	11.69 d	16.33 b
I_3	12.88 d	13.77 c	14.18 c	10.95 e	16.27 b	F_3	13.07 c	17.47 a
Biom. Y t ha^{-1}								
I_1	22.63 ef	25.29 c	26.79 ab	21.89 e	27.92 b	F_1	19.89 f	27.33 c
I_2	26.25 b	25.5 c	27.5 a	22.89 d	29.94 a	F_2	21.19 e	28.03 b
I_3	21.96 f	23.04 de	23.75 d	19.30 f	26.53 c	F_3	23.00 d	29.03 a
Harvest index								
I_1	0.45 a	0.45 a	0.43 b	0.46 a	0.42 c	F_1	0.45 a	0.40 d
I_2	0.40 cd	0.45 a	0.41 bcd	0.43 b	0.40 d	F_2	0.45a	0.42 c
I_3	0.42 bc	0.40 cd	0.41 bcd	0.43 b	0.39 e	F_3	0.43 b	0.40 d
Number of tillers/hill								
I_1	25.50 b	25.50 b	25.33 b	25.33cd	25.56 c	F_1	23.56 c	25.44 b
I_2	25.50 b	28.50 a	28.17 a	26.56 b	28.22 a	F_2	29.11 a	23.56 c
I_3	22.50 c	25.00 b	26.00 b	24.89 d	24.11 e	F_3	24.11 c	28.89 a
Plant height (cm)								
I_1	82.67de	81.92ef	84.25 c	83.56 b	82.33 c	F_1	81.61 d	83.07 c
I_2	82.98 d	86.47 a	85.42 b	84.2 b	85.71 a	F_2	87.08 a	81.87 d
I_3	81.37 f	85.03bc	81.67 f	83.71 b	81.67 c	F_3	82.78 c	84.78 b
Panicle length (cm)								
I_1	18.62 d	20.37 b	21.70 a	19.68 c	20.78ab	F_1	18.97d	18.83 d
I_2	19.27cd	19.97bc	22.40 a	20.00 c	21.09 a	F_2	19.43 d	20.90 b
I_3	18.82 d	20.17 b	19.88bc	18.96 d	20.29bc	F_3	20.23 c	22.42 a
Weight of 1000 grain								
I_1	20.34 d	20.34 d	20.51 a	20.39 a	20.40 b	F_1	20.30 f	20.35 d
I_2	20.39 c	20.43 b	20.51 a	20.38 c	20.51 a	F_2	20.38 c	20.33 e
I_3	20.25 f	20.30 e	20.40 c	20.33 d	20.31 d	F_3	20.41 b	20.54 a

Means designed by the same letter at each cell are not significantly different at the 5% level according to Duncan's multiple range test
n.s: Indicate not significant..

The highest mean values of GY, SY, Biom Y, number of tillers/hill, plant height, panicle length and weight of 1000 grains were obtained from I_2 x M_2, while the lowest mean values of GY, SY and Biom Y, panicle length and weight of 1000 grains were obtained from I_3 x M_1.

The highest mean values of GY, SY, Biom Y, number of tillers/hill, panicle length and weight of 1000 grains were obtained from F_3 x M_2, while the lowest mean values of GY, SY, Biom Y, number of tillers/hill and weight of 1000 grains were obtained from F_1 x M_1 These results could be attributed to the exchangeable effect of ammonia levels and planting methods differences.

Data in Table (5) show that the average values of GY, SY, Biom Y, harvest index, number of tillers/hill, plant height, panicle length and weight of 1000 grains were significantly affected by the interaction between irrigation intervals, ammonia levels and planting methods. The highest mean values of GY were obtained under I_1 x M_2 x F_2, I_1 x M_2 x F_3, I_2 x M_2 x F_2, I_2 x M_2 x F_3 without any significant differences between them however the highest mean values for SY, Biom Y, number of tillers/hill, plant height, panicle length and weight of 1000 grains were obtained under I_2 x M_2 x F_3. While the lowest mean values of GY, SY, Biom Y, panicle length and weight of 1000 grains were under I_3 x M_1 x F_1 interaction treatment.

Table (5): The interaction between irrigation intervals x ammonia levels x planting methods on rice yield and its components.

Irrigation	Planting methods X Ammonia levels					
	M_1			M_2		
	F_1	F_2	F_3	F_1	F_2	F_3
	GY in t ha-1					
I_1	9.32 e	10.10 d	10.65 c	11.13 b	12.20 a	12.12 a
I_2	9.30 e	10.33 cd	10.13 d	11.45 b	12.42 a	12.40 a
I_3	8.00 f	8.07 f	9.00 e	10.17 d	10.47 cd	10.15 d
	SY t ha-1					
I_1	10.43 i	11.82 h	13.35 g	14.37 f	16.47 de	17.46 bc
I_2	12.70 g	11.58 h	14.62 f	16.67 d	17.85 b	19.05 a
I_3	9.92 i	11.68 h	11.25 h	15.83 e	15.87 e	17.1 cd
	Biom. Y t ha^{-1}					
I_1	19.75 k	21.92 j	24.00 i	25.5 g	28.67 d	29.58 bc
I_2	22.00 j	21.92 j	24.75 h	29.08 cd	30.25 ab	30.50 a
I_3	17.92 l	19.75 k	20.25 k	26.00 fg	26.33 f	27.25 e
	Harvest index					
I_1	0.47 a	0.46 a	0.44 b	0.44 bc	0.43 cd	0.41 ef
I_2	0.42 de	0.47 a	0.41ef	0.38 h	0.43 cd	0.41 ef
I_3	0.45 b	0.41 ef	0.45 b	0.39 g	0.40 efg	0.37 h
	Number of tillers/hill					
I_1	24.67 e	29.00 ab	22.33 g	26.33 d	22.00 g	28.33 bc
I_2	23.67 f	28.67 ab	27.33 c	27.33 c	28.33 bc	29.00 ab
I_3	22.33 g	29.67 a	22.67 g	22.67 g	20.33 h	29.33 ab
	Plant height (cm)					
I_1	81.17 hi	84.67 c	84.83 c	84.17 cde	79.17 j	83.67cdef
I_2	82.93 efg	88.50 ab	81.17 hi	83.04defg	84.43 c	89.67 a
I_3	80.73 i	88.07 b	82.33 fgh	82.00 ghi	82.00 ghi	81.00 hi
	Panicle length (cm)					
I_1	18.90 ef	19.73 cde	20.40 bcd	18.33 f	21.00 b	23.00 a
I_2	19.70 cde	19.20 ef	21.10 b	18.83 ef	20.73 bc	23.7 a
I_3	18.30 f	19.37 def	19.20 ef	19.33 def	20.97 b	20.57 bc
	Weight of 1000 grain					
I_1	20.35 ef	20.37 de	20.43 c	20.32 fg	20.30 g	20.58 a
I_2	20.30 g	20.41 cd	20.42 c	20.48 b	20.44 c	20.60 a
I_3	20.25 h	20.35 ef	20.38 de	20.25 h	20.25 h	20.42 c

Irrigation water applied (IWA):

Mean values of water used in treatments I_1, I_2 and I_3 were 13921, 12291 and 10958 m^3 ha^{-1}, respectively (Table 6). Increase irrigation intervals decreased IWA

(Bouman and Tuong, 2001 and Ashouri, 2012). Regarding mean values of water applied in planting methods, M_1 received the highest amount of IWA to be 14338 m^3 ha^{-1} compared to M_2, which was 10443 m^3 ha^{-1}, respectively. The amount of water used in M_2 is a feasible amount to grow rice with a 27.2% saving of water. Atta (2005), Atta *et al.* (2006), Meleha *et al.* (2008) and El-Atawy (2012) they found that planting rice at the bottom of beds saved water by 35.2%, compared to traditional planting. It is obvious that the amount of IWA, which is applied gradually, increased as a result of increased vegetative growth which requires a higher amount of water to meet plant demand. These findings are attributed to the growth stage of the rice and the accompanying weather conditions to growth stages.

Table (6): Irrigation water applied (m^3 ha^{-1}) as related to planting methods, ammonia levels and irrigation intervals as a mean for the two season 2014 and 2015.

Treatments			land preparation of the nursery	Seedling raising (30 days)	preparation of the permanent field and landing	June	July	August	Total
M_1 (Flat)	F_1	I_1	210	345	2037	5494	5668	2391	16144
		I_2	210	345	٢٠٣٧	5265	5393	1066	14316
		I_3	210	345	2037	3562	4177	2213	12544
	F_2	I_1	210	345	2037	5470	5693	2386	16140
		I_2	210	345	٢٠٣٧	5226	5441	1070	14328
		I_3	210	345	2037	3575	4169	2220	12556
	F_3	I_1	210	345	2037	5502	5667	2398	16159
		I_2	210	345	٢٠٣٧	5250	5401	1072	14315
		I_3	210	345	2037	3567	4173	2207	12539
M_2 (Bed)	F_1	I_1	210	345	1624	3838	3990	1679	11687
		I_2	210	345	1624	3602	3737	738	10257
		I_3	210	345	1624	2696	2894	1601	9370
	F_2	I_1	210	345	1624	3818	4022	1683	11702
		I_2	210	345	1624	3589	3765	734	10268
		I_3	210	345	1624	2704	2890	1594	9367
	F_3	I_1	210	345	1624	3840	4000	1675	11694
		I_2	210	345	1624	3585	3771	728	10263
		I_3	210	345	1624	2710	2900	1586	9375
Overall mean			M_1 = 14338			M_2 = 10443			
			I_1 = 13921			I_2 = 12291		I_3 = 10958	
			F_1 = 12386			F_2 = 12394		F_3 = 12391	

Water productivity (WP):

Data in Table (7) shows that mean values of WP of rice (kg grain/m^3 of IWA) is affected significantly by irrigation intervals, ammonia levels and planting methods. Results show that planting treatment M_2 increased WP by 56% compared by M_1. Similar results were reported by Vethaiya *et al.* (2003), Atta (2005), Atta *et al.* (2006) and Choudhury *et al.* (2007), Meleha *et al.* (2008) and El-Atawy (2012). Results also indicate that the highest values of WP were recorded for I_2 whereas the lowest one was obtained from I_1. The high values of WP of I_2 proved its superiority over I_1 and I_3 treatments by 16% and 7%, respectively these results agree with Bouman and Tuong (2001). These results can be attributed to the significant differences in grain yield and evapotranspiration due to water applied values. No significant differences between F_2 and F_3 on WP

The interaction between irrigation intervals, ammonia levels and planting methods showed that the highest WP was 1.21 kg GY per m^3 of IWA was obtained from I_2 x M_2 x F_2 and I_2 x M_2 x F_3. The lowest WP was 0.58 kg grain yield/ $m^3$of IWA was obtained from I_1 x M_1 x F_1.

Nitrogen utilization efficiency (NUE):

Data in Table (7) shows that mean values of NUE of rice (kg grain for each unit N applied) is affected significantly by irrigation intervals, ammonia levels and planting methods. Results show that planting treatment M_2 increased NUE by 21% compared by M_1. The highest values of NUE were recorded for I_1 and I_2 without any significant differences between them whereas the lowest one was obtained from I_3. Also, the highest mean value of NUE was obtained under F_1whereas the lowest was under F_3. Increase in nitrogen application level nitrogen accumulation in plants increased, but nitrogen-use efficiency decreased Zhong-cheng *et al*. (2012). The interaction between irrigation intervals, ammonia levels and planting methods showed that the highest NUE was 163.57 kg grain yield/ one unit N applied was obtained from I_2 x M_2 x F_1 while, the lowest NUE was 100 kg grain yield/ one unit N applied was obtained from I_3 x M_1 x F_3.

Table (7): Influence of planting methods, ammonia levels and irrigation intervals on productivity of irrigation water and nitrogen utilization efficiency for rice as mean for 2014 and 2015 seasons over both seasons.

Irrigation	Planting methods X Ammonia levels						Over all means
	M_1			M_2			
	F_1	F_2	F_3	F_1	F_2	F_3	
	WP						
I_1	0.58 h	0.65 g	0.64 g	0.95 e	1.12 b	1.09 bc	0.81 c
I_2	0.63 g	0.72 f	0.64 g	1.04 d	1.21 a	1.12 b	0.94 a
I_3	0.66 g	0.71 f	0.72 f	1.03 d	1.21 a	1.08 c	0.88 b
Over all means	M_1= 0.70 b			M_2= 1.09 a			
	F_1= 0.84 b		F_2= 0.89 a		F_3= 0.90 a		
	NUE						
I_1	133.10 fg	126.25 h	118.33 i	159.05 b	152.5 c	134.67 ef	137.32 a
I_2	132.86 fg	129.17 gh	112.59 j	163.57 a	155.21 bc	137.78 e	138.53 a
I_3	114.29 ij	100.83 k	100.00 k	145.24 d	130.83 fgh	112.78 j	117.33 b
Over all means	M_1= 118.60 b			M_2= 143.51			
	F_1= 141.39 a		F_2= 132.46 b		F_3= 119.36 c		

Means designed by the same letter at each cell are not significantly different at the 5% level according to Duncan's multiple range test.

CONCLUSIONS

Because the demand for irrigation water is increasing and the development of new water resources is expensive, irrigation water productivity in rice production should be improved. From this study, it can be concluded that irrigation water applied to rice fields can be significantly reduced without sacrificing yields or increasing production costs by using irrigation interval of I_2 (irrigation every six days after transplanting) under M_2 (transplanting in raised beds only) and ammonia gas injection F_2 (80 unit nitrogen). Method of transplanting at the bottom of raised beds increased WP by 56% and save IWA by 27.2% compared to M_1. Therefore, M_2 could be used by the farmers' under irrigation interval of I_2 and ammonia gas injection F_2 because it saved irrigation water by 36% and increased NUE by 17% compared to M_1 x I_1 x F_1 which in normally practiced in North Delta, Egypt.

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تأثر محصول الأرز وانتاجية المياه بالزراعة على مصاطب وفترات الري ومستويات الحقن بالأمونيا الغازية في شمال دلتا النيل

محمود محمد عبدالله محمود

معهد بحوث الاراضى والمياه والبيئة - مركز البحوث الزراعية - الجيزة - مصر.

أجريت تجربة حقلية بمحطة البحوث الزراعية بسخا بشمال دلتا النيل (مصر) خلال الموسمين الزراعيين ٢٠١٤ و ٢٠١٥ وذلك لدراسة تأثير الزراعة على مصاطب وفترات الري والحقن بالأمونيا الغازية على المحصول وانتاجية مياة الري للارز . حيث كان تصميم التجربة قطع منشقة مرتين في اربعة مكررات، حيث وضعت مستويات الحقن بالأمونيا الغازية في القطع الرئيسية بينما وضعت معاملات الرى فى القطع التحت رئيسية ووضعت طرق الزراعة فى القطع التحت تحت رئيسية . كانت مستويات الحقن بالأمونيا الغازية ٧٠ وحدة نيتروجين للفدان (F_1) و٨٠ وحدة نيتروجين للفدان (F_2) و٩٠ وحدة نيتروجين للفدان (F_3) وكانت طرق الزراعة (الزراعة التقليدية فى ارض مستوية (M_1) والزراعة على مصاطب (M_2)) وكانت فترات الرى (الرى كل ٤ أيام (I_1) والرى كل ٦ أيام (I_2) والرى كل ٨ أيام (I_3)).

أوضحت النتائج أنة لا يوجد فرق معنوى لمحصول الحبوب بين المعاملات (I_1) و (I_2) بينما توجد فروق معنوية لمحصول القش والمحصول البيولوجى وباقى مكونات المحصول بين المعاملات (I_1) و(I_2) و(I_3) حيث كانت اعلى القيم لمحصول القش والمحصول البيولوجى وباقى مكونات المحصول تحت المعاملة (I_2) مقارنة بالمعاملات (I_1) و(I_3) .. وبالنسبة لطرق الزراعة فان محصول الحبوب ومحصول القش والمحصول الحيوى قد اذداد بمقدار ٢٠,٨% و٤٠,٤% و ٣١,٧% على الترتيب للمعاملة (M_2) مقارنة بالمعاملة (M_1). لايوجد فرق معنوى بالنسبة للمحصول ومكوناتة بين المعاملات (F_2) و(F_3) ماعدا محصول القش والمحصول الحيوى.

كانت متوسط قيم مياه الرى المضافة للمعاملة (M_1) اكبر من المعاملة (M_2) حيث كانت كمية مياه الري المضافة 14338 م٣/ هكتار و 10443 م٣/هكتار للمعاملات (M_1) و (M_2) على الترتيب حيث كانت كمية مياه الري المضافة للمعاملة (M_2) كافية للحصول على محصول جيد مع توفير ٢٧,٢ % من مياه الري مقارنة بالمعاملة (M_1). وكانت قيم انتاجية المياه تحت المعاملة (I_2) اعلى من المعاملات (I_1) و(I_3) بمقدار ١٦% و ٧% على الترتيب.

طريقة الزراعة (M_2) تزيد كفاءة استخدام النيتروجين بمقدار ٢١% مقارنة بالمعاملة (M_1). و سجلت أعلى قيم لكفاءة استخدام النيتروجين تحت المعاملات (I_1) و (I_2) دون وجود فرق معنوى بينهما بينما كانت أقل القيم بعد المعاملة (I_3). وكذلك كانت أعلى قيم لكفاءة استخدام النيتروجين تحت المعاملة (F_1) بينما كانت أقل القيم بعد المعاملة (F_3).

لذلك يمكن للمزارعين تطبيق طريقة الزراعة على مصاطب (M_2) وذلك مع فترة الري كل ٦ ايام (I_2) مع التسميد بمعدل ٨٠ وحدة نيتروجين للفدان على صورة امونيا غازية (F_2) لأنها توفر مياه الري بمقدار ٣٦% وتزيد كفاءة استخدام النيتروجين بمقدار ١٧% مقارنة بالمعاملة M_1 x I_1 x F_1 الشائع اتباعها لدى المزارعين بمنطقة شمال دلتا النيل دون نقص في المحصول .