

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



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## 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 productivity of irrigation water (PIW) 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 that 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<sup>3</sup> ha<sup>-1</sup> compared to  $M_2$  which was 10443 m<sup>3</sup> ha<sup>-1</sup>, 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 PIW of  $I_2$  proved its superiority over  $I_1$  and  $I_3$  treatments by 16% and 7%, respectively. Planting methods 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  $M_1 \times I_1 \times F_1$  which is 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), productivity of irrigation water (PIW), 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<sup>-1</sup>), followed by drill sowing through a bed planter (6.0 t ha<sup>-1</sup>), 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 PIW 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%, PIW by 66%, and water savings by 38% (Meleha *et al.*, 2008). Transplanting rice in bottom of beds significantly increased grain yield and PIW 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<sup>-1</sup>. The EC of the irrigation water was 0.45 dS m<sup>-1</sup>. The previous crops were clover and wheat in the 1<sup>st</sup> and 2<sup>nd</sup> 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 2014 and 2015 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 <sup>-1</sup>	Mean MJm <sup>-2</sup> d <sup>-1</sup>	Mean mm d <sup>-1</sup>
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.	33.50	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 <sup>3</sup>	Field Capacity %	Permanent wilting point %	Available Water %	pH	EC dsm <sup>-1</sup>
	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<sub>1</sub>), transplanting in raised beds only (M<sub>2</sub>). Irrigation intervals were: irrigation every four days after transplanting (I<sub>1</sub>), irrigation every six days after transplanting (I<sub>2</sub>) and irrigation every eight days after transplanting (I<sub>3</sub>). 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<sub>1</sub> 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<sup>3</sup>/s),

C = Coefficient of discharge = 0.62 (determined by experiment),

A = Inner cross section area of the irrigation spile (cm<sup>2</sup>),

G = Gravity acceleration (cm/s<sup>2</sup>) and

H = Average effective head (cm).

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

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

**Where :** Q = volume of water m<sup>3</sup>/ plot,

q = discharge (m<sup>3</sup>/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 15<sup>th</sup> of May in 2014 and 19<sup>th</sup> of May in 2015. Twenty-five days old seedlings were transplanted in hills spaced 20 X 20 cm for M<sub>1</sub> and 10 X 40 cm in the two rows at the bottom of beds for M<sub>2</sub>. All treatments had 25 hills m<sup>-2</sup>. 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<sub>1</sub> and from the fourth bed in M<sub>2</sub> 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<sup>2</sup> (6m x7m) and GY, SY, and Bioms Y were harvested from 20 m<sup>2</sup>. Grain yield was calculated based on the adjustment to grain moisture content of 140 g kg<sup>-1</sup>. Biomass yield includes grain and straw yield.

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

#### **Productivity of irrigation water (PIW)**

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

$$\text{PIW (Kg /m}^3\text{)} = \frac{\text{Grain yield in kg ha}^{-1}}{\text{Amount of applied water in m}^3\text{ ha}^{-1}}$$

#### **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:

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

**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 of 1000 grain for M<sub>2</sub> compared with M<sub>1</sub>, however harvest index and plant height were highly significant under M<sub>1</sub> compared with M<sub>2</sub>. Grain yield, straw yield and biomass yield increased by 20.8%, 40.4% and 31.7% under M<sub>2</sub> compared with M<sub>1</sub> 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<sub>1</sub> and I<sub>2</sub>, while there were a significant difference on SY, BiomY and other yield components between I<sub>1</sub>, I<sub>2</sub> and I<sub>3</sub>. the highest values were obtained under I<sub>2</sub> compared I<sub>1</sub> and I<sub>3</sub> except harvest index was highly significant under I<sub>1</sub> compared to I<sub>2</sub> and I<sub>3</sub> (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 <sub>1</sub>	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 <sub>2</sub>	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 <sub>1</sub>	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 <sub>2</sub>	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 <sub>3</sub>	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 <sub>1</sub>	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 <sub>2</sub>	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 <sub>3</sub>	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<sub>2</sub> and F<sub>3</sub> except SY and BiomY. Harvest index was higher in F<sub>2</sub> than F<sub>3</sub>. The lowest values were obtained from F<sub>1</sub> 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 from Table 3 that the highest mean values of GY was under I<sub>1</sub> x F<sub>2</sub>, I<sub>1</sub> x F<sub>3</sub>, I<sub>2</sub> x F<sub>2</sub> and I<sub>2</sub> x F<sub>3</sub> 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<sub>2</sub> x F<sub>3</sub> whereas the lowest was under I<sub>3</sub> x F<sub>1</sub>. 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 <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>	M <sub>1</sub>	M <sub>2</sub>	Ammonia	M <sub>1</sub>	M <sub>2</sub>
	GY in t ha <sup>-1</sup>			GY in t ha <sup>-1</sup>			GY in t ha <sup>-1</sup>	
I <sub>1</sub>	10.23 b	11.15 a	11.39 a	10.02 d	11.82 b	F <sub>1</sub>	8.87 e	10.92 b
I <sub>2</sub>	10.38 b	11.38 a	11.27 a	9.92 d	12.09 a	F <sub>2</sub>	9.50 d	11.69 a
I <sub>3</sub>	9.08 d	9.27 cd	9.58 c	8.36 e	10.26 c	F <sub>3</sub>	9.93 c	11.56 a
SYt ha <sup>-1</sup>								
I <sub>1</sub>	12.4 d	14.14 c	15.41 b	11.87 d	16.10 b	F <sub>1</sub>	11.02 e	16.42 b
I <sub>2</sub>	15.88 ab	14.13 c	16.23 a	12.97 c	17.86 a	F <sub>2</sub>	11.69 d	16.33 b
I <sub>3</sub>	12.88 d	13.77 c	14.18 c	10.95 e	16.27 b	F <sub>3</sub>	13.07 c	17.47 a
Biom. Y t ha <sup>-1</sup>								
I <sub>1</sub>	22.63 ef	25.29 c	26.79 ab	21.89 e	27.92 b	F <sub>1</sub>	19.89 f	27.33 c
I <sub>2</sub>	26.25 b	25.5 c	27.5 a	22.89 d	29.94 a	F <sub>2</sub>	21.19 e	28.03 b
I <sub>3</sub>	21.96 f	23.04 de	23.75 d	19.30 f	26.53 c	F <sub>3</sub>	23.00 d	29.03 a
Harvest index								
I <sub>1</sub>	0.45 a	0.45 a	0.43 b	0.46 a	0.42 c	F <sub>1</sub>	0.45 a	0.40 d
I <sub>2</sub>	0.40 cd	0.45 a	0.41 bcd	0.43 b	0.40 d	F <sub>2</sub>	0.45a	0.42 c
I <sub>3</sub>	0.42 bc	0.40 cd	0.41 bcd	0.43 b	0.39 e	F <sub>3</sub>	0.43 b	0.40 d
Number of tillers/hill								
I <sub>1</sub>	25.50 b	25.50 b	25.33 b	25.33cd	25.56 c	F <sub>1</sub>	23.56 c	25.44 b
I <sub>2</sub>	25.50 b	28.50 a	28.17 a	26.56 b	28.22 a	F <sub>2</sub>	29.11 a	23.56 c
I <sub>3</sub>	22.50 c	25.00 b	26.00 b	24.89 d	24.11 e	F <sub>3</sub>	24.11 c	28.89 a
Plant height (cm)								
I <sub>1</sub>	82.67de	81.92ef	84.25 c	83.56 b	82.33 c	F <sub>1</sub>	81.61 d	83.07 c
I <sub>2</sub>	82.98 d	86.47 a	85.42 b	84.2 b	85.71 a	F <sub>2</sub>	87.08 a	81.87 d
I <sub>3</sub>	81.37 f	85.03bc	81.67 f	83.71 b	81.67 c	F <sub>3</sub>	82.78 c	84.78 b
Panicle length (cm)								
I <sub>1</sub>	18.62 d	20.37 b	21.70 a	19.68 c	20.78ab	F <sub>1</sub>	18.97d	18.83 d
I <sub>2</sub>	19.27cd	19.97bc	22.40 a	20.00 c	21.09 a	F <sub>2</sub>	19.43 d	20.90 b
I <sub>3</sub>	18.82 d	20.17 b	19.88bc	18.96 d	20.29bc	F <sub>3</sub>	20.23 c	22.42 a
Weight of 1000 grain								
I <sub>1</sub>	20.34 d	20.34 d	20.51 a	20.39 a	20.40 b	F <sub>1</sub>	20.30 f	20.35 d
I <sub>2</sub>	20.39 c	20.43 b	20.51 a	20.38 c	20.51 a	F <sub>2</sub>	20.38 c	20.33 e
I <sub>3</sub>	20.25 f	20.30 e	20.40 c	20.33 d	20.31 d	F <sub>3</sub>	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<sub>2</sub> x M<sub>2</sub>, while the

lowest mean values of GY, SY and Biom Y, panicle length and weight of 1000 grains were obtained from  $I_3 \times M_1$ .

The highest mean values of GY, SY, Biom Y, number of tillers/hill, panicle length and weight of 1000 grains were obtained from  $F_3 \times M_2$ , while the lowest mean values of GY, SY, Biom Y, number of tillers/hill and weight of 1000 grains were obtained from  $F_1 \times M_1$ . 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  $I_1 \times M_2 \times F_2$ ,  $I_1 \times M_2 \times F_3$ ,  $I_2 \times M_2 \times F_2$ ,  $I_2 \times M_2 \times F_3$  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  $I_2 \times M_2 \times F_3$ . While the lowest mean values of GY, SY, Biom Y, panicle length and weight of 1000 grains were under  $I_3 \times M_1 \times F_1$  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 <sub>1</sub>			M <sub>2</sub>		
	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>
	GY in t ha <sup>-1</sup>					
I <sub>1</sub>	9.32 e	10.10 d	10.65 c	11.13 b	12.20 a	12.12 a
I <sub>2</sub>	9.30 e	10.33 cd	10.13 d	11.45 b	12.42 a	12.40 a
I <sub>3</sub>	8.00 f	8.07 f	9.00 e	10.17 d	10.47 cd	10.15 d
	SYt ha <sup>-1</sup>					
I <sub>1</sub>	10.43 i	11.82 h	13.35 g	14.37 f	16.47 de	17.46 bc
I <sub>2</sub>	12.70 g	11.58 h	14.62 f	16.67 d	17.85 b	19.05 a
I <sub>3</sub>	9.92 i	11.68 h	11.25 h	15.83 e	15.87 e	17.1 cd
	Biom. Y t ha <sup>-1</sup>					
I <sub>1</sub>	19.75 k	21.92 j	24.00 i	25.5 g	28.67 d	29.58 bc
I <sub>2</sub>	22.00 j	21.92 j	24.75 h	29.08 cd	30.25 ab	30.50 a
I <sub>3</sub>	17.92 l	19.75 k	20.25 k	26.00 fg	26.33 f	27.25 e
	Harvest index					
I <sub>1</sub>	0.47 a	0.46 a	0.44 b	0.44 bc	0.43 cd	0.41 ef
I <sub>2</sub>	0.42 de	0.47 a	0.41ef	0.38 h	0.43 cd	0.41 ef
I <sub>3</sub>	0.45 b	0.41 ef	0.45 b	0.39 g	0.40 efg	0.37 h
	Number of tillers/hill					
I <sub>1</sub>	24.67 e	29.00 ab	22.33 g	26.33 d	22.00 g	28.33 bc
I <sub>2</sub>	23.67 f	28.67 ab	27.33 c	27.33 c	28.33 bc	29.00 ab
I <sub>3</sub>	22.33 g	29.67 a	22.67 g	22.67 g	20.33 h	29.33 ab
	Plant height (cm)					
I <sub>1</sub>	81.17 hi	84.67 c	84.83 c	84.17 cde	79.17 j	83.67cdef
I <sub>2</sub>	82.93 efg	88.50 ab	81.17 hi	83.04defg	84.43 c	89.67 a
I <sub>3</sub>	80.73 i	88.07 b	82.33 fgh	82.00 ghi	82.00 ghi	81.00 hi
	Panicle length (cm)					
I <sub>1</sub>	18.90 ef	19.73 cde	20.40 bcd	18.33 f	21.00 b	23.00 a
I <sub>2</sub>	19.70 cde	19.20 ef	21.10 b	18.83 ef	20.73 bc	23.7 a
I <sub>3</sub>	18.30 f	19.37 def	19.20 ef	19.33 def	20.97 b	20.57 bc
	Weight of 1000 grain					
I <sub>1</sub>	20.35 ef	20.37 de	20.43 c	20.32 fg	20.30 g	20.58 a
I <sub>2</sub>	20.30 g	20.41 cd	20.42 c	20.48 b	20.44 c	20.60 a
I <sub>3</sub>	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<sub>1</sub>, I<sub>2</sub> and I<sub>3</sub> were 13921, 12291 and 10958 m<sup>3</sup> ha<sup>-1</sup>, 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<sub>1</sub> received the highest amount of IWA to be 14338 m<sup>3</sup> ha<sup>-1</sup> compared to M<sub>2</sub>, which was 10443 m<sup>3</sup> ha<sup>-1</sup>, respectively. The amount of water used in M<sub>2</sub> 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<sup>3</sup> ha<sup>-1</sup>) 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 <sub>1</sub> (Flat)	F <sub>1</sub>	I <sub>1</sub>	210	345	2037	5494	5668	2391	16144	
		I <sub>2</sub>	210	345	2037	5265	5393	1066	14316	
		I <sub>3</sub>	210	345	2037	3562	4177	2213	12544	
	F <sub>2</sub>	I <sub>1</sub>	210	345	2037	5470	5693	2386	16140	
		I <sub>2</sub>	210	345	2037	5226	5441	1070	14328	
		I <sub>3</sub>	210	345	2037	3575	4169	2220	12556	
	F <sub>3</sub>	I <sub>1</sub>	210	345	2037	5502	5667	2398	16159	
		I <sub>2</sub>	210	345	2037	5250	5401	1072	14315	
		I <sub>3</sub>	210	345	2037	3567	4173	2207	12539	
M <sub>2</sub> (Bed)	F <sub>1</sub>	I <sub>1</sub>	210	345	1624	3838	3990	1679	11687	
		I <sub>2</sub>	210	345	1624	3602	3737	738	10257	
		I <sub>3</sub>	210	345	1624	2696	2894	1601	9370	
	F <sub>2</sub>	I <sub>1</sub>	210	345	1624	3818	4022	1683	11702	
		I <sub>2</sub>	210	345	1624	3589	3765	734	10268	
		I <sub>3</sub>	210	345	1624	2704	2890	1594	9367	
	F <sub>3</sub>	I <sub>1</sub>	210	345	1624	3840	4000	1675	11694	
		I <sub>2</sub>	210	345	1624	3585	3771	728	10263	
		I <sub>3</sub>	210	345	1624	2710	2900	1586	9375	
Overall mean			M <sub>1</sub> = 14338			M <sub>2</sub> = 10443				
			I <sub>1</sub> = 13921			I <sub>2</sub> = 12291			I <sub>3</sub> = 10958	
			F <sub>1</sub> = 12386			F <sub>2</sub> = 12394			F <sub>3</sub> = 12391	

**Productivity of irrigation water (PIW):**

Data in Table (7) shows that mean values of PIW of rice (kg grain/m<sup>3</sup> of IWA) is affected significantly by irrigation intervals, ammonia levels and planting methods. Results show that planting treatment M<sub>2</sub> increased PIW by 56% compared by M<sub>1</sub>. 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 PIW were recorded for I<sub>2</sub> whereas the lowest one was obtained from I<sub>1</sub>. The high values of PIW of I<sub>2</sub> proved its superiority over I<sub>1</sub> and I<sub>3</sub> 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<sub>2</sub> and F<sub>3</sub> on PIW

The interaction between irrigation intervals, ammonia levels and planting methods showed that the highest PIW was 1.21 kg GY per m<sup>3</sup> of IWA was obtained from I<sub>2</sub> x M<sub>2</sub> x F<sub>2</sub> and I<sub>2</sub> x M<sub>2</sub> x F<sub>3</sub>. The lowest PIW was 0.58 kg grain yield/ m<sup>3</sup> of IWA was obtained from I<sub>1</sub> x M<sub>1</sub> x F<sub>1</sub>.

**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<sub>2</sub> increased NUE by 21% compared by M<sub>1</sub>. The highest values of NUE were recorded for I<sub>1</sub> and I<sub>2</sub> without any significant differences between them whereas the lowest one was obtained from I<sub>3</sub>. Also, the highest mean value of NUE was obtained under F<sub>1</sub> whereas the lowest was under F<sub>3</sub>. 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<sub>2</sub> x M<sub>2</sub> x F<sub>1</sub> while, the lowest NUE was 100 kg grain yield/ one unit N applied was obtained from I<sub>3</sub> x M<sub>1</sub> x F<sub>3</sub>.

**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 <sub>1</sub>			M <sub>2</sub>			
	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>	
	WP						
I <sub>1</sub>	0.58 h	0.65 g	0.64 g	0.95 e	1.12 b	1.09 bc	0.81 c
I <sub>2</sub>	0.63 g	0.72 f	0.64 g	1.04 d	1.21 a	1.12 b	0.94 a
I <sub>3</sub>	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 <sub>1</sub> = 0.70 b			M <sub>2</sub> = 1.09 a			
	F <sub>1</sub> = 0.84 b		F <sub>2</sub> = 0.89 a		F <sub>3</sub> = 0.90 a		
	NUE						
I <sub>1</sub>	133.10 fg	126.25 h	118.33 i	159.05 b	152.5 c	134.67 ef	137.32 a
I <sub>2</sub>	132.86 fg	129.17 gh	112.59 j	163.57 a	155.21 bc	137.78 e	138.53 a
I <sub>3</sub>	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 <sub>1</sub> = 118.60 b			M <sub>2</sub> = 143.51			
	F <sub>1</sub> = 141.39 a		F <sub>2</sub> = 132.46 b		F <sub>3</sub> = 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<sub>2</sub> (irrigation every six days after transplanting) under M<sub>2</sub> (transplanting in raised beds only) and ammonia gas injection F<sub>2</sub> (80 unit nitrogen). Method of transplanting at the bottom of raised beds increased PIW by 56% and save IWA by 27.2% compared to M<sub>1</sub>. Therefore, M<sub>2</sub> could be used by the farmers' under irrigation interval of I<sub>2</sub> and ammonia gas injection F<sub>2</sub> because it saved irrigation water by 36% and increased NUE by 17% compared to M<sub>1</sub> x I<sub>1</sub> x F<sub>1</sub> which in normally practiced in North Delta, Egypt.

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**تأثر محصول الأرز وإنتاجية مياه الري بالزراعة على مصاطب وفترات الري ومستويات الحقن بالأمونيا الغازية في شمال دلتا النيل**  
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**معهد بحوث الاراضى والمياه والبيئة - مركز البحوث الزراعية - الجيزة - مصر.**

أجريت تجربة حقلية بمحطة البحوث الزراعية بسخا بشمال دلتا النيل ( مصر) خلال الموسمين الزراعيين 2014 و 2015 وذلك لدراسة تأثير الزراعة على مصاطب وفترات الري والحقن بالأمونيا الغازية على المحصول وانتاجية مياه الري للارز . حيث كان تصميم التجربة قطع منشقة مرتين في اربعة مكررات, حيث وضعت مستويات الحقن بالأمونيا الغازية في القطع الرئيسية بينما وضعت معاملات الري في القطع التحت الرئيسية ووضعت طرق الزراعة في القطع التحت تحت رئيسية . كانت مستويات الحقن بالأمونيا الغازية 70 وحدة نيتروجين للفدان ( $F_1$ ) و80 وحدة نيتروجين للفدان ( $F_2$ ) و90 وحدة نيتروجين للفدان ( $F_3$ ) وكانت طرق الزراعة (الزراعة التقليدية في ارض مستوية ( $M_1$ ) والزراعة على مصاطب ( $M_2$ ) ) وكانت فترات الري (الري كل 4 ايام ( $I_1$ ) والري كل 6 ايام ( $I_2$ ) والري كل 8 ايام ( $I_3$ )).

أوضحت النتائج أنه لا يوجد فرق معنوي لمحصول الحبوب بين المعاملات ( $I_1$ ) و ( $I_2$ ) بينما توجد فروق معنوية لمحصول القش والمحصول البيولوجي وباقي مكونات المحصول بين المعاملات ( $I_1$ ) و ( $I_2$ ) و ( $I_3$ ) حيث كانت اعلى القيم لمحصول القش والمحصول البيولوجي وباقي 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 20,8% و40,4% و31,7% على الترتيب للمعاملة ( $M_2$ ) مقارنة بالمعاملة ( $M_1$ ). لا يوجد فرق معنوي بالنسبة للمحصول ومكوناته بين المعاملات ( $F_2$ ) و ( $F_3$ ) ماعدا محصول القش والمحصول الحيوى.

كانت متوسط قيم مياه الري المضافة للمعاملة ( $M_1$ ) اكبر من المعاملة ( $M_2$ ) حيث كانت كمية مياه الري المضافة 14338 م<sup>3</sup>/هكتار و 10443 م<sup>3</sup>/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 27,2% من مياه الري مقارنة بالمعاملة ( $M_1$ ). وكانت قيم انتاجية مياه الري تحت المعاملة ( $I_2$ ) اعلى من المعاملات ( $I_1$ ) و ( $I_3$ ) بمقدار 16% و 7% على الترتيب. طريقة الزراعة ( $M_2$ ) تزيد كفاءة استخدام النيتروجين بمقدار 21% مقارنة بالمعاملة ( $M_1$ ). و سجلت أعلى قيم لكفاءة استخدام النيتروجين تحت المعاملات ( $I_1$ ) و ( $I_2$ ) دون وجود فرق معنوي 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 6 ايام ( $I_2$ ) مع التسميد بمعدل 80 وحدة نيتروجين للفدان على صورة امونيا غازية ( $F_2$ ) لأنها توفر مياه الري بمقدار 36% وتزيد كفاءة استخدام النيتروجين بمقدار 17% مقارنة بالمعاملة  $F_1 \times I_1 \times M_1$  الشائع اتباعها لدى المزارعين بمنطقة شمال دلتا النيل دون نقص في المحصول .