Journal of Plant Production

Journal homepage: www.jpp.mans.edu.eg
Available online at: www.jpp.journals.ekb.eg

Behavior of some Micronutrients and Water Productivity in Rice Soil Under Irrigation Intervals and Organic and Inorganic Fertilizes

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ABSTRACT

A field experiment was carried out to investigate the effect of organic and inorganic fertilizers and their combinations under different irrigation intervals on yield and its attributes of the Giza178 rice cultivar, as well as, the availability of some micronutrients in the soil. Irrigation treatments were continuous flooding (CF), continuous saturation (CS), irrigation every 6 days (E6D), every 9 days (E9D) and every 12 days (E12D), while the fertilizer treatments were control (without fertilizer), 5t cattle manure ha^{-1} (CM), 5t compost ha^{-1} (C), 5t cattle manure +110 kg N ha^{-1} (CM+110N), 5t compost +110 kg N ha^{-1} (C+110N) and the recommended N rate of 165 kg N ha^{-1} (165N). Prolonged irrigation intervals of more than 6 days substantially decreased the yield and its attributes, Fe and Mn concentration in the soil in both seasons. The opposite was true for Zn concentration. Fertilizer sources containing chemical N (165N) alone or 110N with C or CM significantly surpassed each of the two organic sources alone in yield and yield attributes in the two seasons. The application of C+110N fertilizer with irrigation E6D was statistically at par with the recommended interaction (CF irrigation X 165N fertilizer) in yield and its attributes. The total amount of irrigation water applied was decreased by prolonging the irrigation interval. The inverse was true for water saved and water productivity in kg grains m^{-3}. Application of C+110N fertilizer with irrigation E6D recorded the highest water productivity and saved water > 3000 m^3 in the two seasons.

Keywords: Rice, compost, water stress, drought, zinc.

INTRODUCTION

Rice (*Oryza sativa*, L.) is one of the most important cereal crops in the world as well as in Egypt. Most Egyptian rice genotypes show better growth and higher productivity under continuous flooding conditions than under water deficit at certain growth stages (El-Refaee *et al.*, 2012). The current quantities and sources of available water in Egypt are 55.5 billion cubic meters (BCM) $yr^{-1}$from the River Nile and around 10.5 BCM from other sources, mainly rain and underground water. However, the total water requirement for agriculture, urban areas, etc. is estimated to be 79.5 BCM yr^{-1} or even more, creating a gap of more than 13.5 BCM yr^{-1} (Mohie El-Din and Moussa, 2016). Recently, the term "water-saving irrigation methods" has been introduced, which recommends, (i) reducing the depth of ponded water from 5-7 cm to 2-3 cm height to reduce the amount of water used for irrigation, (ii) keeping the soil just saturated by irrigation until the soil is wet (Daniela and Bruce, 2016).

Soil moisture regimes affect the availability and uptake of nutrients (Hazra and Chandra, 2014), affecting processes of mineralization and solubilization in soils as well as the composition and magnitude of the soil microbiota. Micronutrients are as important as macronutrients in plant nutrition. The deficiency of micronutrients is considered one of the most important causes of declining productivity trends in rice growing. Micronutrients are needed in trace amounts but their adequate supply improves nutrient availability and positively affects the cell physiology that is reflected in yield as well (Dass *et al.*, 2017; Carrijo *et al.*, 2017 and Kazemalilou *et al.*, 2021).

Continuous flooding of rice soil causes sharp increases in the availability of iron (Fe), manganese (Mn) and molybdenum (Mo) (Prakash *et al.*, 2007). Biswas *et al.*, (2007) have reported that the total uptakes of N, P, K, Ca, Mg, Mn, Fe and S were higher under flooded conditions compared with non-flooded conditions.

The application of organic fertilizers such as the farmyard manure and compost could increase the soil organic matter which includes serving several advantages like conservation and slow release of nutrients, enhance soil chemical and physical conditions and preservation of soil moisture that help for high production (Ghoneim, 2020). Alternate flooding and drying gave highest rice grain yield and nitrogen and some micronutrients uptake than continuous flooding (Gewaily *et al.*, 2011 and Moe *et al.*, 2019). Organic manures provide nutrients to the soil and improve water holding capacity and contribute to the soil ability to maintain better aeration for seed germination and root development (Moe *et al.*, 2020). Iqbal *et al.*, (2020) suggested that poultry manure or cattle manure combined with chemical fertilizer at a ratio of 30:70 is a better plan for achieving maximum rice yields with improved soil health. This enhancement in soil nutrients was associated with organic manure (cattle) absorbing more leachate generated during the process, which resulted in enhanced water holding capacity, reduced nutrient leaching, and consequentially more available nutrients in the soil.

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DOI: 10.21608/jpp.2021.82510.1037

Due to the differences in the behavior of micronutrients under flooded soil compared to irrigation intervals so, we need to know the best recommendation of organic fertilizers under irrigation intervals. A study was, therefore, carried out with water and organic fertilizer management to investigate the yield potential with the following objectives 1) to find out the suitable irrigation practice to save water, 2) to determine the suitable fertilizer package, 3) to study the combined effects of irrigation and fertilizer on yield, and 4) study the Fe, Mn and Zn availability in soil under water stress, which may help in better nutrient management and consequently greater yields.

MATERIALS AND METHODS

Field experiment was conducted at the Experimental Farm of Sakha Agriculture Research Station, Kafr El-Sheikh, Egypt, during 2019 and 2020 seasons to study the impact of irrigation intervals and organic fertilizer sources on yield and its attributes of Giza178 rice cultivar as well as the availability of Fe, Mn and Zn at different periods 30, 60 and 90 days after transplanting (DAT). Irrigation intervals were continuous flooding (CF), continuous saturation (CS), irrigation every 6 days (E6D), every 9 days (E9D) and every 12 days (E12D). Fertilizer sources were control (without fertilizer), 5t cattle manure ha^{-1} (CM), 5t compost ha^{-1} (C), 5t cattle manure +110 kg N ha^{-1} (CM+110N) , 5t compost +110 kg N ha^{-1} (C+110N) and the recommended N rate of 165 kg N ha^{-1} (165N). Chemical analysis of compost and cattle manure was presented in Table 1. The experiment was laid out in a Strip Plot Design with four replications. Irrigation treatments were located in the horizontal plots, while the fertilizers treatments were placed in the vertical plots. The plot size was 24 m^2 (4×6 m) in both seasons. To avoid the lateral movement of water and to achieve more water control, each block was separated by two-meter-wide ditches. Water pump, provided with a calibrated water meter, was used for all water measurements. Irrigation treatments started after 15 days from transplanting. The chemical characteristics of the experimental soil (Richards, 1954) are specified in Table 2.

Table 1. Some chemical properties of organic fertilizer in 2019 and 2020 seasons.

Organic source	season	C %	N %	C:N ratio	P%	K%	Fe ppm	Mn ppm	Zn ppm
Compost (C)	2019	31.0	1.81	17.12	0.49	0.67	490	305	61.0
	2020	29.0	1.86	15.59	0.61	0.73	560	423	78.0
Cattel manure (CM)	2019	40.0	1.90	21.05	0.71	0.37	529	213	43.5
	2020	38.9	2.10	18.52	0.79	0.41	542	193	64.0

Table 2. Chemical analysis of the experimental soil (0-30 cm) in 2019 and 2020 seasons.

Season	pH (1:2.5)	EC (ds/m)	OM %	Available (ppm)			DTPA extract (ppm)		
				N	P	K	Zn	Mn	Fe
2019	8.2	3.2	1.32	25.18	11.42	328	0.90	3.1	4.55
2020	8.3	3.39	1.43	20.13	10.98	334	1.12	2.9	4.5

Full dose of phosphorus 37 kg P_2O_5 ha^{-1} as a superphosphate (15% P_2O_5) was applied as a basal application during land preparation and incorporated well into the dry soil. Zinc as zinc sulphate at the rate of 24 kg ha^{-1} was applied in the nursery after wet leveling. Seeds at the rate of 140 kg ha^{-1} were soaked in water for 24 hr then incubated for 48 hr to hasten germination. Pre-germinated seeds were uniformly broadcasted in the nursery on 7th and 1st May of the two seasons, respectively. The permanent field was well prepared, i.e. plowed twice followed by good wet leveling. After 30 days from sowing the nursery, the seedlings were pulled and transferred to the permanent field and transplanted at the spacing 20×20 cm between rows and hills. The organic fertilizers were applied into soil and incorporated two weeks before first irrigation. The nitrogen fertilizer was added as urea (46.5% N) according to the experimental treatments. Two third of N was applied as basal application, and the other third was top dressed at 30 days after transplanting (DAT). At harvesting number of panicles m^2 were counted. Ten main panicles were collected randomly to estimate the number of filled grains per panicle and 1000-grain weight. The total weight of both grain and straw were determined from 10 m^2 of each plot then; the yields were calculated as tons per hectare. The weight of grains was adjusted to 14% moisture content. Water productivity (WP) was calculated as the weight of grains per unit of water used (kg grains m^3 water). Soil samples were taken at 30, 60 and 90 days after transplanting (DAT), all samples were subjected to determination of available Fe, Mn and Zn according to the methods of Cottenie *et al.*, (1982).

Collected data were subjected to statistical analysis according to procedure describe by Gomes and Gomes (1984). Means were compared at $p < 0.05$ using Duncan's multiple tests (MRT), which was adapted by Duncan (1955).

RESULTS AND DISCUSSION

Yield and its attributes:

Tables 3 and 4 showed that panicle numbers m^{-2}, filled grain $panicle^{-1}$, and 1000-grain weight of the Giza178 rice cultivar were affected by irrigation intervals and fertilizer sources in the 2019 and 2020. Irrigation intervals had a significant effect on all yield attributes in the two seasons. A prolonged irrigation interval than 6 days substantially decreased the number of panicle m^{-2}, filled grains $panicle^{-1}$ and 1000 grains weight compared with continuous flooding (CF), continuous saturation (CS) and every 6 days (E6D). CF recorded the greatest values of all yield attributes, while irrigation every 12 days (E12D) recorded the lowest ones in both seasons. CS and E6D were statically at par with CF in these traits. Data in Table 5 indicated that CF, CS and E6D being insignificant, resulted in a significant increase in straw and grain yields compared with E9D and E12D irrigation in the two seasons. Rice plants received irrigation every 12 days (E12D) produced the lowest straw and grain yields compared with other irrigation intervals. The increase in grain yield with sufficient irrigation water (CF, CS and

E6D) may be due to a considerable increase in growth, which is reflected in higher grain yield attributes (number of panicle m^{-2}, number of filled grains $panicle^{-1}$ and 1000-grain weight) and in turn, increased grain yield. Moreover, the yield and its attributes were decreased by prolonging the irrigation intervals gradually from continuous flooding to irrigation every 12 days. In this connection, adequate water allowed the rice plant to increase its photosynthetic rate, which enhanced the grain size and ultimately caused a higher grain yield. It could be attributed to the fact that the available water enhances nutrient availability and improved nutrients (macro and micro) uptake by plants, as well as enhanced the production and translocation of dry matter to panicles (sink) and consequently higher grain yield. In contrast, water deficit leads to a reduction in the efficiency of physiological processes, including protein synthesis, photosynthesis, respiration, and nucleic acid synthesis, causes inhibition the activities of many enzymes and leads to changes in the ultra-structures of plant tissues. These results agreed with those obtained by Gewaily *et al.,* (2011), El-Habet, (2014) and Kazemalilou *et al.,* (2021). The shortage of water might have caused a decrease in the activity of nodes and buds that reduces the emergence of tillers especially the effective tillers and number and area of leaves due to the decrease in cell division and elongation. These results are in agreement with those of El-Refaee *et al,* (2012) and Elhabet, (2018).

Yield attributes (Tables 3 & 4) as well as, straw yield and grain yield (Table 5) were significantly affected by fertilizer sources in both seasons. Application of any fertilizer source pronouncedly increased panicle numbers m^{-2}, filled grains $panicle^{-1}$, 1000-grain weight, straw yield and grain yield compared with control treatment in the two seasons. Fertilizer sources containing chemical N (165N) alone or 110N with organic fertilizers (C or CM) significantly surpassed each of the two organic sources alone in straw yield, grain yield panicle numbers m^{-2} and filled grains $panicle^{-1}$ in the two seasons. Data in Table 4 shows that the application of compost alone or with chemical N fertilizer was more effective on 1000 grains weight than the other fertilizer sources. The application of N fertilizer alone with the recommended rate (165N) was statistically at par with CM+110N and C+110N in straw yield and grain yield in the two seasons. These treatments increased the number of panicles of m^{-2}, the number of filled grains in $panicle^{-1}$, and the 1000-grain weight to produce the highest grain yield. The application of organic and chemical N fertilizer to rice enhanced the availability of nutrients in the soil solution. The available nutrients might have helped in the stimulation of various physiological processes including cell division and cell elongation of internodes resulting in more tillers formation, leaf numbers and photosynthetic area (leaf area), which resulted in more photosynthetic production and consequently increased dry matter accumulation, yield attributes and grain yield. These results are compatible with those observed by Gewaily *et al.,* (2011) and Elhabet, (2018). El-Hity *et al.,* (2020) reported that mineral fertilizers accompanying with compost significantly improved grain yield and its attributes of Egyptian hybrid rice.

Table 3. Number of panicles m^{-2} and number of filled grains $panicle^{-1}$ of Giza178 rice cultivar as affected by irrigation interval (I), fertilizer source (F) and their interaction in 2019 and 2020 seasons.

Treatments	Irrigation intervals (I)					
Fertilizer source (F)	**CF**	**CS**	**E6D**	**E9D**	**E12D**	**Mean-F**
Number of panicles m^{-2} in 2019 season						
Control	425 ij	421 ij	419 j	392 k	373 k	406 D
CM	478 def	473 d-g	467 d-g	448 ghi	422 ij	458 C
C	490 cd	481 de	472 d-g	453 e-h	432 hij	465 C
CM +110 N	539 ab	532 ab	529 ab	488 cd	452 fgh	508 B
C+110 N	548 a	542 ab	536 ab	514 bc	469 d-g	522 A
165 N	544 a	537 ab	533 ab	494 cd	455 e-h	512 AB
Mean-I	504 A	498 A	493 A	465 B	434 C	
Number of panicles m^{-2} in 2020 season						
Control	422 kl	415 kl	410 lm	390 mn	371 n	402 C
CM	480 efg	471 fgh	468 ghi	454 hij	435 jk	462 B
C	493 ef	489 efg	472 fgh	468 ghi	446 ij	474 B
CM +110 N	546 abc	544 a-d	524 cd	494 ef	475 e-h	517 A
C+110 N	553 a	549 ab	548 abc	527 bcd	495 ef	535 A
165 N	547 abc	541 a-d	521 d	498 e	478 e-h	517 A
Mean-I	507 A	502 A	491 AB	472 BC	450 C	
Number of filled grains $panicle^{-1}$ in 2019 season						
Control	121 lm	113 no	111o	107 o	95 p	109D
CM	135 d-h	133 f-j	129 g-k	118 mn	107 o	125C
C	140 a-f	138 b-f	134 e-i	127 i-l	113 no	130BC
CM +110 N	142 a-d	141 a-e	139 a-f	133 f-j	122 klm	135AB
C+110 N	146 a	144 ab	142 a-d	137 b-f	128 h-l	139A
165 N	143 abc	142 a--d	140 a-f	136 c-g	126 jkl	137AB
Mean-I	138A	135A	133A	126B	115C	
Number of filled grains $panicle^{-1}$ in 2020 season						
Control	128 f-j	124 g-k	118 kl	105 m	104 m	116C
CM	134 b-f	131 d-i	130 e-i	123 h-l	115 l	127B
C	139 a-e	136 a-f	133 b-g	128 f-j	118 kl	131AB
CM +110 N	141 abc	140 a-d	139 a-e	130 e-i	121 jkl	134A
C+110 N	144 a	142 ab	142 ab	132 c-h	122 i-l	136A
165 N	142 ab	141 abc	140 a-d	131 d-i	119 kl	134A
Mean-I	138A	136A	134A	125B	117C	

Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test. Capital letter for the main effect and small letter for the interaction effect.

Table 4. 1000-grain weight (g) of Giza178 rice cultivar as affected by irrigation interval (I), fertilizer source (F) and their interaction in 2019 and 2020 seasons.

Treatments	Irrigation intervals (I)					
Fertilizer source (F)	**CF**	**CS**	**E6D**	**E9D**	**E12D**	**Mean-F**
			1000-grain weight (g) in 2019 season			
Control	21.82 ab	21.20 a-e	20.39 def	18.27 g	17.53 g	19.84C
CM	21.74 abc	21.38 a-d	20.67 b-f	20.43 c-f	19.65 f	20.77B
C	21.90 ab	21.50 a-d	21.34 a-d	20.77 b-f	19.92 ef	21.09AB
CM +110 N	21.55 a-d	21.29 a-d	21.20 a-e	20.57 b-f	19.61 f	20.85B
C+110 N	22.12 a	22.12 a	22.11 a	20.66 b-f	20.27 def	21.46A
165 N	21.80 ab	21.18 a-e	21.15 a-e	19.54 f	18.26 g	20.39C
Mean-I	21.82A	21.45A	21.14A	20.04B	19.21C	
			1000-grain weight (g) in 2020 season			
Control	21.55 c-g	21.49 c-g	21.80 fg	20.15 h	18.93 j	20.64B
CM	21.70 b-f	21.62 c-g	21.20 g	20.11 hi	19.50 j	20.70B
C	21.96 a-d	21.83 a-e	21.27 efg	20.23 h	19.53 ij	20.97AB
CM +110 N	21.62 c-g	21.49 c-g	21.10 g	20.10 hi	19.32 j	20.71B
C+110 N	22.13 abc	22.39 a	22.27 ab	21.45 d-g	19.91 hi	21.63A
165 N	22.12 abc	21.65 b-g	21.37 d-g	20.29 h	19.29 j	20.94B
Mean-I	21.85A	21.75A	21.34A	20.39B	19.34C	

Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test. Capital letter for the main effect and small letter for the interaction effect.

The interaction between irrigation intervals and fertilizer sources had a significant effect on panicle numbers m^{-2} and filled grains $panicle^{-1}$ (Table 3), 1000 grains weight (Table 4), straw yield and grain yield (Table 5) in the two seasons. The relative ranking of the interaction between irrigation intervals and fertilizer sources for all straw and grain yields as well as all yield attributes was inconsistent in both seasons. Generally, all the combinations of CF and CS with 165N, C+110N and CM+110N were among those treatments having high straw yield, grain yield and its attributes in both seasons. Irrigation E12D X without fertilizer interaction recorded the lowest values of the above-mentioned traits, being insignificant, in both seasons. The application of C+110N fertilizer with irrigation E6D was statistically at par with the recommended interaction (CF irrigation X 165N fertilizer) in straw, grain yield and all its attributes. The increase in grain yield might be due to the presence of the required amount of both water and fertilizer. The gradual decomposition of compost released nitrogen and other nutrients which make continuous supply to the plant at different stages of growth. Moreover, the organic fertilizers kept water in the soil longer as shown in E6D and E9D treatments compared to other fertilizer treatments by the same irrigation interval (El-Refaee, 2007 and Elhabet, 2018). *Gewaily et al.,* (2011) found that continuous flooding and saturation under organic fertilizer had a highly significant effect on grain yield. The highest straw biomass might be due to the presence of adequate amount of both nitrogen fertilizer and water which led to increase the availability of NH_4^+ and its uptake. The increase in N absorption always increase the absorption of both P, K, Fe, Mn and Zn which increase both of number of tillers and leaves that significantly increase in straw yield. It can be easily observed that the combination of 5 tons C+110 kg N ha^{-1} with (E6D, E9D and E12D) reduced the hazard effect of water stress and increased straw yield and reach to the maximum value when compared to other fertilizer treatments by the same irrigation interval. These results agreed with Bhardwaj *et al.,* (2020) and Dhaliwal *et al.,* (2020) who found that there are significant differences among fertilizer treatments on straw yield under water stress. Iqbal *et al.,* (2020) suggested that poultry manure or cattle manure combined with chemical fertilizer at a ratio of 30:70 is a better plan for achieving maximum rice yields with improved soil health. This enhancement in soil nutrients was associated with organic manure (cattle) absorbing more leachate generated during the process, which resulted in enhanced water holding capacity, reduced nutrient leaching, and consequentially more available nutrients in the soil.

Some water relations

Total amount of irrigation water applied (WA):

Irrigation treatments were started at 15 DAT to harvest. Total amount of applied water in all irrigation intervals was 1761 and 1783 m^3 ha^{-1} during nursery preparation, raising seedling (30 days), permanent field preparation, transplanting and 15 DAT in both seasons, respectively. The amounts of applied irrigation water (WA) from nursery preparation to harvest as affected by irrigation water level are presented in Table 6 and Figure 1. Total amount of irrigation water applied (WA) from nursery preparation to harvest were decreased by prolonging the irrigation interval in both seasons. The total amount of water applied were 15108, 12131, 12030, 11434 and 10336 m^3 ha^{-1} in the first season and 15238, 12336, 12138, 11636 and 10434 m^3 ha^{-1} in the second season for CF, CS, E6D, E9D and E12D, respectively. Such increase in WA by shortening the irrigation interval may be attributed to considerable increase in growth, which resulted in a greater transpiration and in turn water requirement. These results are harmony with those obtained with El-Refaee *et al.,* (2012); Ibrahim *et al.,* (2017); Moe *et al.,* (2017) and Elhabet, (2018).

Table 5. Grain and straw yield (t ha^{-1}) of Giza178 rice cultivar as affected by irrigation interval (I), fertilizer source (F) and their interaction in 2019 and 2020 seasons.

Treatments	Irrigation intervals (I)					
Fertilizer source (F)	**CF**	**CS**	**E6D**	**E9D**	**E12D**	**Mean-F**
			Straw yield (t ha^{-1}) in 2019 season			
Control	5.52 m-p	5.19 nop	5.33 nop	4.80 op	3.98 p	4.96 C
CM	8.08 jkl	7.82 jkl	7.65 jkl	6.97 klm	5.95 mno	7.29 B
C	9.18 f-j	8.96 g-j	8.64 hij	8.01 jkl	6.75 lmn	8.31 B
CM +110 N	11.76 abc	11.34 a-e	10.70 b-f	10.14 d-h	9.17 f-j	10.62 A
C+110 N	12.80 a	12.50 a	12.26 ab	10.50 c-g	9.80 e-i	11.57 A
165 N	12.40 a	12.10 ab	11.70 a-d	9.80 e-i	8.41 ijk	10.88 A
Mean-I	9.958 A	9.651 A	9.380 A	8.371 B	7.344 C	
			Straw yield (t ha^{-1}) in 2020 season			
Control	6.23 klm	5.70 lmn	5.33 mn	4.90 mn	4.65 n	5.36 C
CM	8.50 ghi	7.99 hij	7.78 hij	7.14 ijk	6.88 jkl	7.66 B
C	8.76 fgh	8.50 ghi	8.29 hij	7.74 hij	7.00 jkl	8.06 B
CM +110 N	11.50 abc	11.19 bcd	10.80 cde	9.95 def	8.56 f-i	10.40 A
C+110 N	12.90 a	12.61 ab	12.25 ab	11.70 abc	9.95 def	11.88 A
165 N	12.30 ab	12.05 abc	11.78 abc	9.75 efg	8.17 hij	10.81 A
Mean-I	10.03 A	9.675 A	9.371 A	8.532 B	7.535 C	
			Grain yield (t ha^{-1}) in 2019 season			
Control	4.40 klm	4.23 k-n	4.07 lmn	3.65 mn	3.45 n	3.96 D
CM	5.34 ij	5.06 ijk	4.89 i-l	4.89 ijkl	4.55 jkl	4.95 C
C	6.53 fg	6.41 fgh	6.36 gh	5.65 hi	5.38 ij	6.07 B
CM +110 N	9.83 ab	9.81 ab	9.39 bc	7.99 d	6.90 efg	8.78 A
C+110 N	10.32 a	10.18 ab	10.17 ab	8.90 c	7.67 de	9.45 A
165 N	10.03 ab	9.99 ab	9.36 bc	7.27 def	6.57 fg	8.64 A
Mean-I	7.74 A	7.61 A	7.38 A	6.39 B	5.75 C	
			Grain yield (t ha^{-1}) in 2020 season			
Control	4.76 ijkl	4.52 jkl	4.24 kl	3.89 lm	3.33 m	4.15 C
CM	5.71 gh	5.44 ghi	5.29 hij	4.81 ijk	4.16 klm	5.08 C
C	6.66 ef	6.67 ef	6.68 ef	6.21 fg	5.63 ghi	6.37 B
CM +110 N	10.09 ab	9.90 abc	9.74 bc	8.17 d	7.20 e	9.02 A
C+110 N	10.72 a	10.49 ab	10.24 ab	9.20c	8.19 d	9.77 A
165 N	10.38 ab	10.21 ab	9.83 abc	8.04 d	7.07 ef	9.10 A
Mean-I	8.05 A	7.87 A	7.67 A	6.72 B	5.93 C	

Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test. Capital letter for the main effect and small letter for the interaction effect.

Table 6. Water productivity (WP) of Giza178 rice cultivar as affected by the interaction between irrigation intervals and fertilizer treatments in 2019 and 2020 seasons.

Treatments	Irrigation interval (I)					
Fertilizer source (F)	**CF**	**CS**	**E6D**	**E9D**	**E12D**	**Mean-F**
			Water productivity (kg grain/m^3 water ha^{-1}) in 2019			
Control	0.291j	0.349hij	0.338hij	0.319ij	0.334ij	0.326C
CM	0.353hij	0.417g-j	0.407g-j	0.428g-j	0.451ghi	0.411BC
C	0.432ghij	0.528efg	0.529efg	0.494fgh	0.522efg	0.501B
CM +110 N	0.611def	0.743a-d	0.739a-d	0.742a-d	0.758a-d	0.719A
C+110 N	0.683bcd	0.839ab	0.846a	0.831ab	0.801abc	0.801A
165 N	0.664cde	0.803abc	0.778abc	0.785abc	0.761a-d	0.758A
Mean-I	0.506B	0.613A	0.606A	0.601A	0.604A	
			Water productivity (kg grain/m^3 water ha^{-1}) in 2020			
Control	0.313m	0.366lm	0.349lm	0.335m	0.357lm	0.344C
CM	0.375klm	0.441jk	0.436jk	0.413jkl	0.465ij	0.426BC
C	0.437jk	0.54h	0.55h	0.516hi	0.541h	0.517B
CM +110 N	0.617g	0.758de	0.753de	0.728ef	0.767cde	0.725A
C+110 N	0.703ef	0.85a	0.844ab	0.848a	0.833abc	0.816A
165 N	0.668fg	0.807a-d	0.81a-d	0.802a-d	0.773b-e	0.772A
Mean-I	0.519B	0.627A	0.624A	0.607A	0.623A	

Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test. Capital letter for the main effect and small letter for the interaction effect.

Figure 1 showed that the amount of saved irrigation water was increased by prolonging the irrigation interval. Saved water were 2977 and 2902 m^3 ha^{-1} for CS, 3078 and 3100 m^3 ha^{-1} for E6D, 3674 and 3602 m^3 ha^{-1} for E9D and 4772 and 4804 m^3 ha^{-1} for E12D than CF irrigation in the two seasons, respectively.

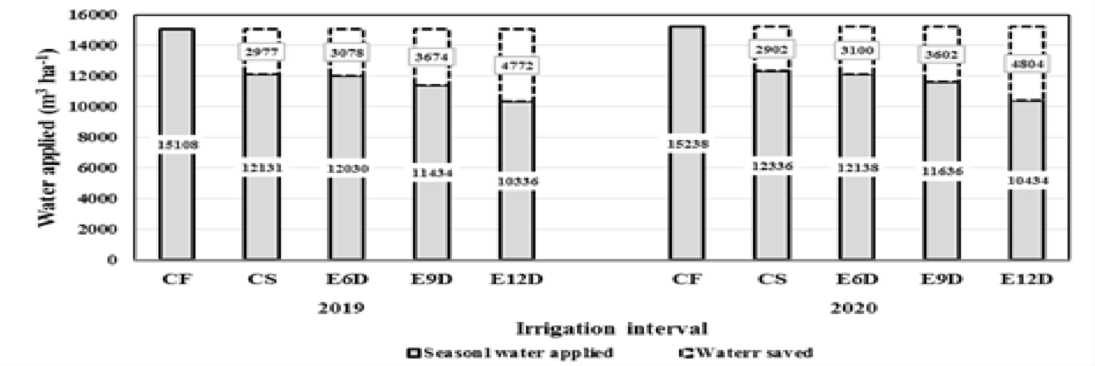

Figure 1. **Seasonal irrigation water applied and water saved (m3/ha-1) as affected by irrigation water levels** in **2019 and 2020 seasons.**

Water productivity:

Grain yield per unit of irrigation water applied (WA) in kg grain m^{-3} water was used to determine water productivity (WP). Data in Table 6 shows that the WP was increased by prolonging the irrigation interval in both seasons. CS, E6D, E9D and E12D irrigation, being insignificant, resulted in a significant increase in WP than CF irrigation in both seasons. The CS and E6D irrigation were statistically at par with CF irrigation in high grain yield, despite being lower in the amount of WA. As a result, WA has increased due to increased grain yield and decreased irrigation water use.

The application of organic fertilizers (C or CM) alone or with chemical fertilizer significantly increases WP than the control treatments in both seasons (Table 6). The highest WP was obtained with the application of C+110N fertilizer, with no significant difference than the application of CM+110N and the recommended N fertilizer (165N). Organic fertilizers cause gradual decomposition, releasing nitrogen and other nutrients which continuous supply to the plant at various stages of growth and in turn increased grain yield. Moreover, the organic fertilizers keep water in the soil longer. Moe *et al.,* (2020) reported that organic manures provide nutrients to the soil and improve water holding capacity and contribute to the soil ability to maintain better aeration for seed germination and root development. Iqbal *et al.,* (2020) suggested that enhancement in soil nutrients was associated with organic manure (cattle) absorbing more leachate generated during the process, which resulted in enhanced water holding capacity, reduced nutrient leaching, and consequentially more available nutrients in the soil.

Table 6 shows WP as affected by the interaction of irrigation intervals and fertilizer sources in the 2019 and 2020 seasons. Irrigation intervals without fertilizer had no significant effect on WP in both seasons. The relative ranking of the interaction between irrigation intervals and fertilizer sources for WP was inconsistent in both seasons.

Generally, all the combinations of CS, E6D, E9D, E12D irrigation with 165N and C+110N fertilizer were among those treatments having high WP with no significant differences in both seasons. Irrigation CF X without fertilizer interaction recorded the lowest values of WP in both seasons. The application of C+110N fertilizer with irrigation E6D recorded the highest WP (0.846 and 0.844 kg grain m^{-3}) in the two seasons. The interaction E6D x C+110N saved > 3000 m^{3} water ha^{-1} and was statistically at par with the recommended interaction (CF irrigation X 165N fertilizer) in grain yield in both seasons. Data indicated that compost enhances water holding capacity.

Micronutrient availability in Soil:

Zinc (Zn) availability

Zinc deficiency is the most widespread micronutrient disorder in rice. The availability of Zn in the soil at 30, 60 and 90 days after transplanting (DAT) as affected by irrigation and fertilizer treatments is presented in Table 7. Data indicated that the highest available concentration of Zn were recorded with E12D followed by E9D at 30, 60 and 90 DAT compared with other irrigation interval in 2019 and 2020 seasons. It could attribute to the reduction in native Zn due to flooding condition and to precipitation of Zn CO_3 due to CO_2 accumulation resulting from organic matter decomposition in soil (Naeem, 2006 and Masunaga and Fong, 2018). Dobermann and Fairhurst (2000) reported that under flooded conditions, Zn availability decreases because of the reduction in Zn solubility.

The highest zinc availability in the soil was observed with C+110N followed by CM+110N and 165N at 30, 60 and 90 DAT. It could be attributed to the decomposition of compost and cattle manure as organic fertilizers which release macro and micro nutrients (Naeem, 2006 and Moe *et al.,* 2019). Data also, revealed that the available concentration of Zn was higher at 30 DAT and 60 DAT, compared with the availability of Zn at 90 DAT during the two seasons.

The concentration of available Zn (ppm) in the soil as affected by the interaction between irrigation intervals and fertilizer treatments in 2019 and 2020 seasons is illustrated in Figure 2. The greatest concentration of available Zn recorded when C+110N, 165N and CM+110N were integrated with both E6D and E9D at 30 DAT, while the lowest value of Zn available was found when combined with CF at 90 DAT in both seasons. It could be attributed to the integration of compost with urea increase Zn availability at 30 days compared to control or urea alone then decreased after that. This may be due to good decomposition of compost, which increases the amount of available Zn. Data showed also that, zinc availability start to decrease continuously with time. This could be attributed to the formation of Zn-phosphates (Dobermann and Fairhurst, 2000 and Kazemalilou *et al.,* 2021). Rengel, (2015) found that soil Zn is usually more available in soils with greater organic matter content.

Table 7. Availability of zinc (Zn) concentration (ppm) in the soil at 30, 60 and 90 DAT as affected by irrigation intervals and fertilizer treatments in 2019 and 2020 seasons.

Factor	Zn at 30 DAT		Zn at 60 DAT		Zn at 90 DAT	
	2019	**2020**	**2019**	**2020**	**2019**	**2020**
Irrigation interval (I)						
CF	1.09e	1.16d	0.90b	0.96c	0.660b	0.70d
CS	1.18d	1.24c	1.11a	1.02c	0.83ab	0.90b
E6D	1.31c	1.39b	1.08a	1.13b	0.82ab	0.83c
E9D	1.36b	1.41b	1.10a	1.16ab	0.950a	0.97a
E12D	1.41a	1.46a	1.15a	1.23a	0.860a	0.90b
F Test	**	**	**	**	*	**
Fertilizer source (F)						
Control	0.87e	0.90e	0.70e	0.73e	0.53d	0.56f
CM	1.04d	1.12d	0.83d	0.89d	0.66d	0.70e
C	1.27c	1.33c	1.02c	1.10c	0.80c	0.85d
CM +110 N	1.45b	1.51b	1.17b	1.24b	0.98ab	1.01b
C+110 N	1.59a	1.65a	1.47a	1.34a	1.06a	1.10a
165 N	1.41b	1.48b	1.21b	1.28ab	0.90bc	0.94c
F Test	**	**	**	**	**	**
Interaction I x F	*	*	**	**	*	*

***, ** and N.S. indicate P< 0.05, P<0.01 and not significant, respectively. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.**

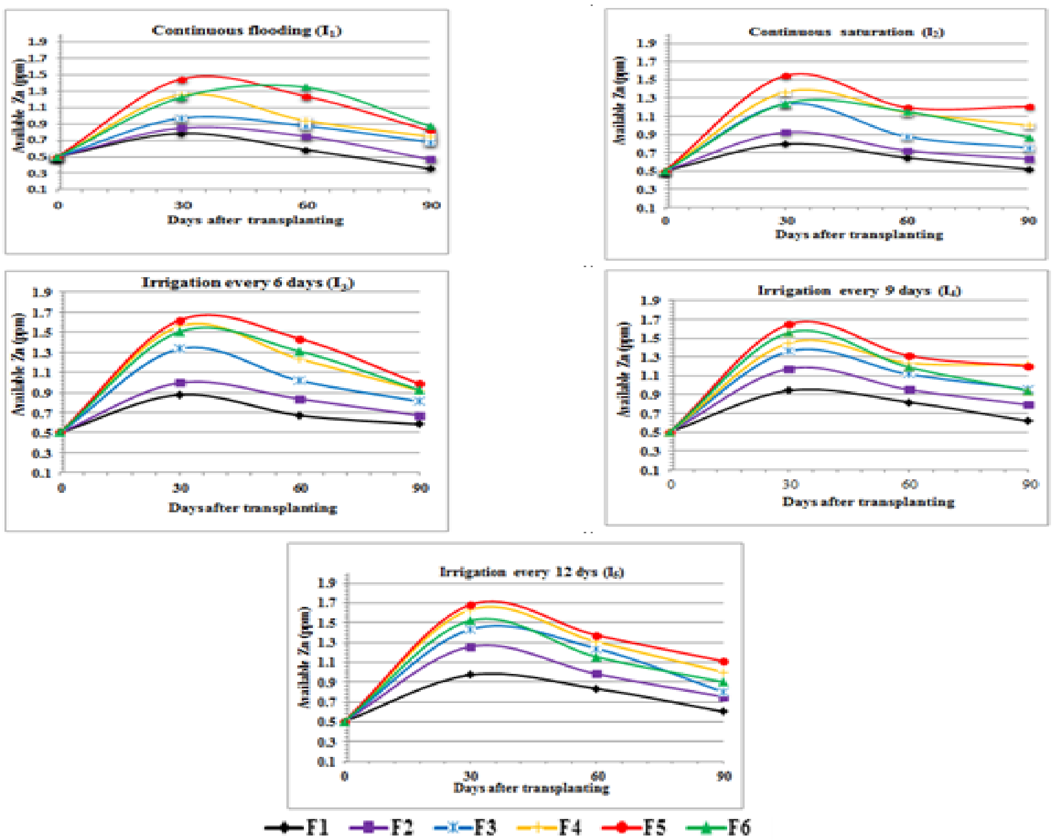

Figure 2. Available Zn concentration in soil (ppm) at 30, 60 and 90 DAT as affected the interaction between irrigation intervals and fertilizer treatments as overall mean values through the two growing seasons. F1: control, F2: CM, F3: C, F4: CM +110 N, F5: C +110 N and F6:165 N.

Iron (Fe) availability:

The availability of Ferrous (Fe^{2+}) in the soil at 30, 60 and 90 DAT as affected by irrigation intervals and fertilizer sources are presented in Table 8. Data showed that the highest available concentration of Fe^{2+} was found with CF followed by CS at 30, 60 and 90 DAT in 2019 and 2020 seasons. Available ferrous (Fe^{2+}) concentration in all treatments increased to a peak at 30 days after transplanting then decreased afterward. The increase in Fe^{2+} in flooding soil can be attributed to the increase of iron solubility as Fe^{3+} is reduced to the more soluble Fe^{2+} under anaerobic conditions. These findings were in agreement with those reported by (Naeem, 2006; El-Habet, 2014 and Moe *et al.*, 2019). Dobermann and Fairhurst, (2000) reported that the concentration of Fe^{2+} peaks at 2-4 weeks following submergence. In general, solution Fe 2+ increases sharply after flooding. Rengel, (2015) found that the most important chemical change that takes place, when soil is flooded, is the reduction of iron and an increase in its solubility in water. The concentration of water-soluble iron increases reaches peaks as high within 1-3 weeks of flooding.

Data in the same Table (8) revealed that the application of organic fertilizer whether, cattle manure or compost increased ferrous (Fe^{2+}) availability compared with the control. The highest of available ferrous (Fe^{2+}) concentration was observed with C+110N followed by CM+110N. It could be attributed to the decomposition of compost and cattle manure as organic fertilizers which release iron. These results are agreed with those obtained by Dass *et al*., (2017) and Mahender *et al*. (2019).

Table 8. Availability of iron (Fe) concentration (ppm) in the soil at 30, 60 and 90 DAT as affected by irrigation intervals and fertilizer treatments in 2019 and 2020 seasons

Factor	Fe at 30 DAT		Fe at 60 DAT		Fe at 90 DAT	
	2019	2020	2019	2020	2019	2020
Irrigation interval (I)						
CF	220.8a	227.1a	207.1a	209.1a	113.3a	115.4a
CS	158.1b	160.4b	148.8b	150.8b	107.7b	104.2b
E6D	129.7c	133.5c	119.2c	123.1c	97.5c	99.6c
E9D	122.5d	129.6d	101.3d	105.0d	89.6d	92.9d
E12D	103.75e	108.4e	93.3e	97.2e	72.5e	75.8e
F Test	**	**	**	**	**	**
Fertilizer source (F)						
Control	117.0f	121.5f	103.0f	105.5f	70.5f	68.5f
CM	134.3e	138.4e	124.5e	125.5e	75.5e	80.5e
C	150.5c	156.9c	136.5d	141.0d	96.3d	99.5d
CM +110 N	159.4b	164.7b	145.0b	149.7b	109.4b	112.0b
C+110 N	171.3a	174.8a	155.0a	157.5a	120.6a	122.0a
165 N	149.5d	154.6d	139.5a	143.2c	104.5c	103c
F Test	**	**	**	**	**	**
Interaction I x F	**	**	**	**	**	**

**** indicates P<0.01. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.**

The concentration of available Fe^{2+} (ppm) in the soil as affected by the interaction between irrigation intervals and fertilizer treatments in the 2019 and 2020 seasons is illustrated in Figure 3. Data demonstrated that the highest available Fe^{2+} was found when C+110N combined with flooded conditions (CF) followed by CS. The increase in Fe^{2+} in flooding condition can be attributed to the increased solubility of Fe^{2+} and it's released from the compost. Moreover, the chelating agents supplied from compost which could help in maintaining the solubility of iron. These findings are in agreement with those obtained by Das, (2000); Ibrahim *et al.*, (2017) and Masunaga and Fong, (2018). Data in the same figure (3) illustrated that the lowest values of available Fe^{2+} were found when control fertilizer combined with E12D irrigation in both seasons. This is mainly due to prolonging irrigation intervals up to 12 days which increased the aerobic conditions and higher amount of oxygen that lead to more ferric (Fe^{3+}). Fe^{3+} is not readily usable by rice plants as well as microbes due to the formation of insoluble oxides or hydroxides (Dotaniya *et al.*, 2013 and Mahender *et al.*, 2019).

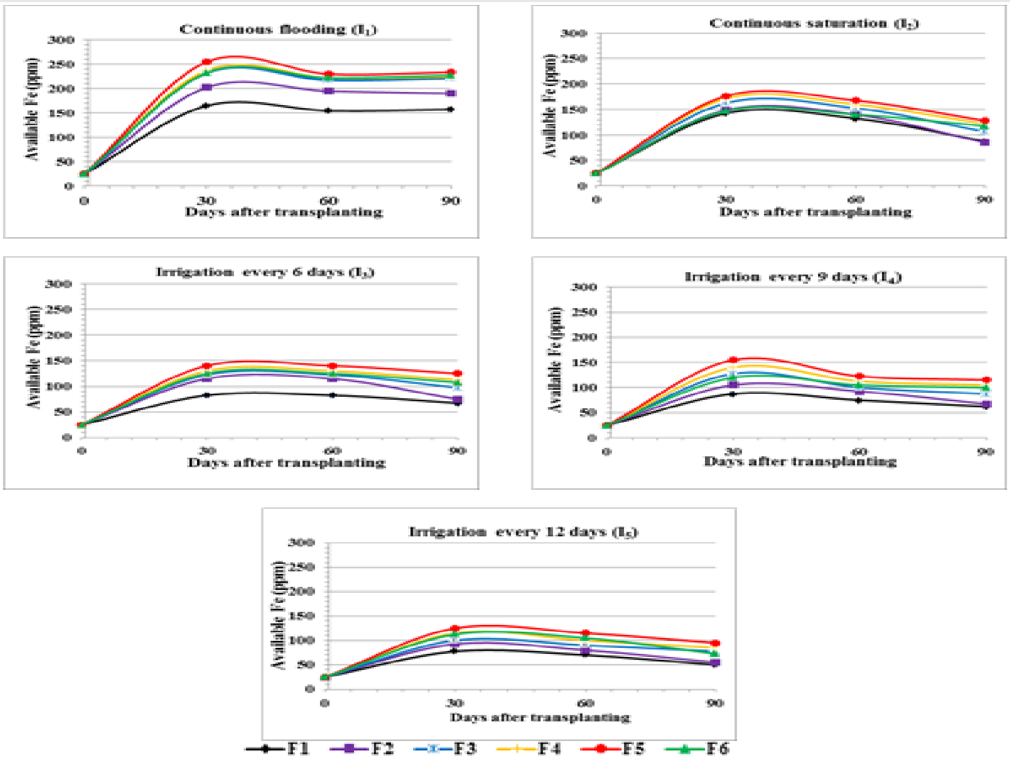

Figure 3. Available Fe concentration in soil (ppm) at 30, 60 and 90 DAT as affected the interaction between irrigation intervals and fertilizer treatments as overall mean values through the two growing seasons. F1: control, F2: CM, F3: C, F4: CM +110 N, F5: C +110 N and F6:165 N.

Manganese (Mn) availability

Table 9 presented the effect of irrigation intervals and fertilizer treatment on manganese (Mn^{2+}) availability in the soil. Data showed that the availability of Mn^{2+} followed the same pattern as that of Fe^{2+}. Available soil Mn^{2+} increased from 3.10 ppm before flooding to 60.40 ppm with control at 30 DAT in first season. The increase in native manganese upon flooding might result from the reduction of manganese (III and IV) oxides to Mn^{2+} (Doberman and Fairhurst, 2000). It is clear from the results that the highest Mn^{2+} availability was found with CF followed by CS at 30 DAT. Dobermann and Fairhurst (2000) reported that Mn deficiency occurs frequently in upland rice, and is uncommon in rainfed or lowland rice because the solubility of Mn increases under submerged conditions. Mn availability starts to decline after 30 days from transplanting. This may be due to the absorption by plants beside complex formations (Sahrawat, 2015). Data in the same Table (9) showed that the highest Mn^{2+} availability was recorded with C+110N followed by CM+110N in 2019 and 2020 seasons. It could be attributed to the decomposition of compost and cattle manure as organic fertilizers which release manganese (Mn).

Table 9. Availability of manganese (Mn) concentration (ppm) in the soil at 30, 60 and 90 days after transplanting (DAT) as affected by irrigation intervals and fertilizer treatments in 2019 and 2020 seasons.

Factor	Mn at 30 DAT		Mn at 60 DAT		Mn at 90 DAT	
	2019	2020	2019	2020	2019	2020
Irrigation interval (I)						
CF	105.7a	109.7a	80.5a	84.2a	51.3a	52.4a
CS	95.0b	100.7b	70.2b	72.8b	47.8b	48.0b
E6D	84.2c	87.8c	63.9c	67.2c	43.5c	45.1c
E9D	77.7d	80.3d	56.8d	59.9d	37.9d	39.8d
E12D	52.3e	59.5e	43.8e	46.2e	29.1e	30.9e
F Test	**	**	**	**	**	**
Fertilizer source (F)						
Control	60.4f	65.4f	45.1f	48.2f	29.7f	31.5f
CM	74.0e	78.8e	57.3e	58.5e	36.3e	37.5e
C	87.5c	92.2c	63.4c	66.8c	41.7d	46.1c
CM +110 N	94.4b	97.4b	70.7b	74.1b	47.0b	49.2b
C+110 N	104.6a	109.0a	80.2a	83.8a	53.9a	52.2a
165 N	80.4d	82.8d	61.4d	65.0d	42.9c	42.9d
F Test	**	**	**	**	**	**
Interaction I x F	**	**	**	**	**	**

** indicates P<0.01. Means of each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

The availability of manganese (Mn^{2+}) in the soil at 30, 60 and 90 DAT as affected by the interaction between irrigation intervals and fertilizer treatments is illustrated in Figure 4. Data indicated that the highest Mn^{2+} available was found when C+110N combined with flooded conditions (CF) followed by saturation irrigation treatments in both seasons. When a soil is flooded, the concentration of water-soluble manganese increases, reaches a peak, and declines. The rate of increase in concentration as well as the peak and final stable concentrations are determined mainly by the manganese and organic matter content of the soil (Rengel, 2015).

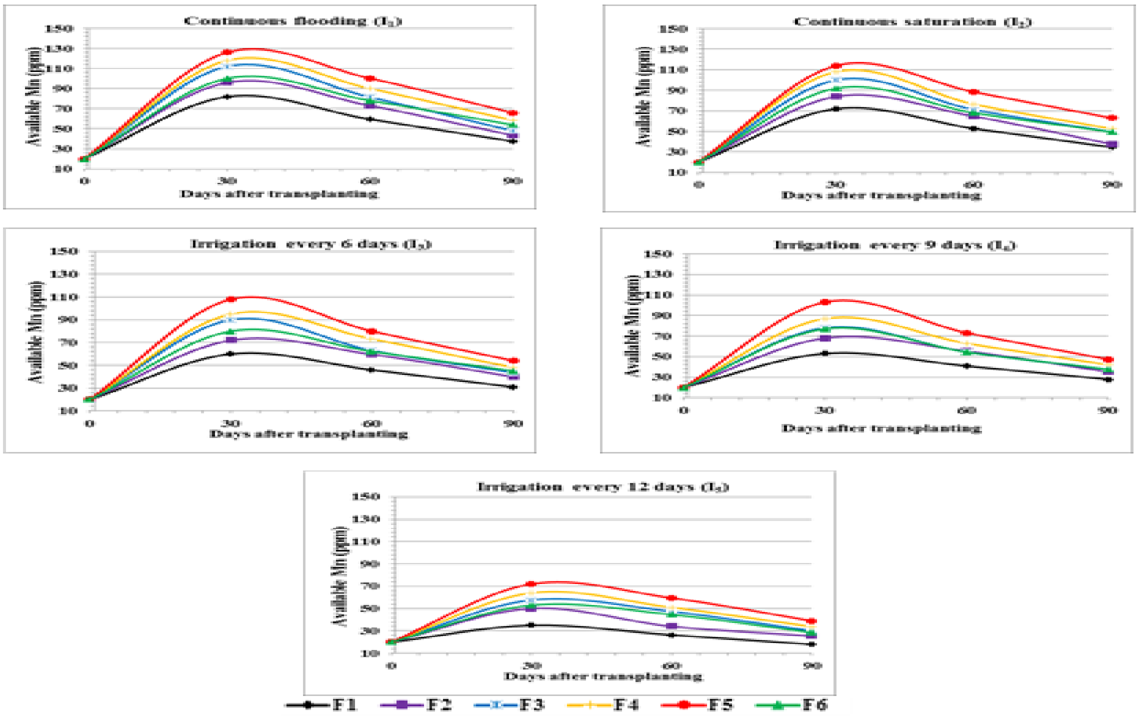

Figure 4. Available Mn concentration in soil (ppm) at 30, 60 and 90 DAT as affected the interaction between irrigation intervals and fertilizer treatments as overall mean values through the two growing seasons. F1: control, F2: CM, F3: C, F4: CM +110 N, F5: C +110 N and F6:165 N.

General measures to prevent Mn deficiency by apply farmyard manure or compost to balance Mn removal and enhance Mn 4+ reduction in rice soil containing small amounts of Mn and organic matter (Dobermann and Fairhurst 2000). From these data, the conclusion can be made that addition compost plus urea increased the manganese availability.

CONCLUSION

It can be concluded that irrigation every 6 days (E6D) with the application of 5t compost + 110 kg N ha^{-1} (C+110N) was the best treatment which was among other treatments having high grain yield, available nutrients and water productivity (WP) and can save greater than 3000 m^3 water ha^{-1} without reducing grain yield compared with the recommended treatments (CF +165N).

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سلوك بعض العناصر الصغري و انتاجية المياه في أرض الأرز تحت فترات الري والأسمدة العضوية وغير العضوية

عبدالفتاح صبحي غريب، سماح محمد عامر و عبده عبدالله زيدان
مركز البحوث والتدريب في الارز-معهد بحوث المحاصيل الحقلية- مركز البحوث الزراعية- كفرالشيخ- مصر.

أجريت تجربتان حقليتان بالمزرعة البحثية بمحطة البحوث الزراعية بسخا- مركز البحوث الزراعية –كفرالشيخ – مصر في موسمي ٢٠١٩ و٢٠٢٠م لدراسة تأثير الأسمدة العضوية و غير العضوية علي محصول الأرز ومكوناته لصنف الأرز جيزة ١٧٨ تحت فترات ري مختلفة وكذلك مدي تيسر بعض العناصر الغذائية الصغري في التربة. وتضمنت معاملات الري (الغمر المستمر، التشبع المستمر و الري كل ٦، ٩ و ١٢ يوما). وتضمنت معاملات الأسمده العضويه وغير العضويه معاملة المقارنة (بدون تسميد) ، ٥ طن سماد أبقار ، ٥ طن كمبوست ، ٥ طن سماد أبقار + ١١٠ كجم نتروجين ، ٥ طن كمبوست + ١١٠ كجم نتروجين للهكتار و المعدل الموصي به من النتروجين ١٦٥كجم للهكتار. أظهرت النتائج ان تطويل فترة الري أكثر من ٦ أيام أدي الي انخفاض كبير في عدد السنابل في المتر المربع و عدد الحبوب الممتلئة في النسبلة ووزن١٠٠٠ حبة ومحصول القش و محصول الحبوب وكذلك تركيز الحديد و المنجنيز في التربة و كمية المياه المستخدمه في كلا الموسمين. كما أظهرت النتائج أن استخدام الأسمدة النيتروجينية منفرده بمعدل ١٦٥ كجم نيتروجين للهكتار أو ١١٠ وحده نتروجين للهكتار مع اي من الكمبوست أو مع سماد الأبقار تفوقت بشكل كبير علي باقى معدلات التسميد تحت الدراسة في المحصول ومكوناته وإنتاجية مياه الرى وتيسر الحديد و المنجنيز والزنك في التربة عند ٣٠، ٦٠، ٩٠ يوم من الشتل في كلا الموسمين. أثر التفاعل بين فترات الرى ومصادر الأسمدة معنويا على جميع الصفات المدروسة. لم تظهر فروق معنوية فى المحصول ومكوناته بين تفاعل الأسمدة العضوية + ١١٠ كجم نيتروجين للهكتار مع الري كل ٦ أيام وبين التفاعل الموصي به (الرى بالغمر المستمر مع التسميد النيتروجينى بمعدل ١٦٥ وحدة نيتروجين للهكتار). ويستنتج من النتائج أن التسميد بمعدل ٥ طن كمبوست + ١١٠كجم نتروجين للهكتار مع الرى كل ٦ أيام تعتبر أفضل المعاملات لتعظيم إنتاجية الأرز حيث أنها من بين المعاملات التى تعطى أعلى محصول حبوب وإنتاجية مياه وتوفر أكثر من ٣٠٠٠ م^{٣} ماء للهكتار بدون نقص معنوى فى المحصول.