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Response of Rice Yield and Yield Components as well as Grain Quality to Number and Levels of Zinc Foliar Spraying Application

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TWO field experiments were conducted during the summer season of 2014 and 2015 growing successive seasons at the Experimental Station of Faculty of Agriculture, Ain Shams University, Shalakan, Kalubia Governorate, Egypt, to investigate the response of rice crop yield and yield components as well as grain quality to the number (once, 45 DAS; twice, 60 DAS and thrice, 75 DAS) and levels (0, 200, 400, 600 and 800ppm Zn) of zinc foliar spraying application. Experimental design was split plot design with three replications, where, number of zinc foliar application occupied the main plots and zinc levels distributed in the sub plots. Application of 600ppm Zn gave the highest values of panicle number/m^2, panicle length, spikelets numbers/panicle, panicle weight, filled grains percent, filled grains numbers/panicle and 1000 grain weight. Foliar application of 600ppm Zn showed the highest values of grain crude protein content, soluble carbohydrate, GNY, SNY, TNY, NRE and NUE. Thrice zinc foliar application gave the maximum values of panicle length, spikelets numbers/panicle, panicle weight, filled grains percent and filled grains numbers/panicle. While, panicle number/m^2 and 1000 grain weight were slightly affected by number of zinc foliar application. Application of thrice zinc foliar application at the level of 600ppm exhibited the highest values of grain, straw, biological and GCP yields as well as most of yield attributes and nitrogen physiological parameters.

Keywords: Rice, Yield and yield attributed, Zinc foliar application, Nitrogen physiological parameters.

Inroduction

Rice (*Oryzae sativa*, L.) is staple food for more than 60% of world population (Parthipan & Ravi, 2016), it is one of the most important cereal crops in Egypt, it plays an important role in the strategy to overcome food shortage and improve self-sufficiency. It is grown in Egypt in area of 1.216 million faddan with an annual production of about 4.82 million tones and with an average yield of 3.96tons per faddan during the year 2015 growing season (CLAC, 2015).

Zinc is one of the most important essential nutrients required for plant growth. It acts as an activator of several enzymes in plants and is directly involved in the biosynthesis of growth substances such as auxin which is involved in plant growth and cell division. Where, zinc represented in all six enzyme classes (oxidoreductases, transferases, hydrolases, lyases, isomerases and ligases) (Auld, 2001). Zinc's function in cell membrane integrity will also be discussed especially for root cells along with its role in suppressing free radical damage to cells (Cakmak, 2000). Also, it is required for chlorophyll production, pollen function, fertilization and germination (Kaya & Higgs, 2002; Pandey et al., 2006 and Cakmak, 2008). Zinc increases the resistance of plants to pathogens by bringing changes in anatomy and physiology of host plant. One of the major roles of micronutrients in plants is to associate with many enzyme systems which were involved in defense mechanism within plants against pathogens. Also, Zinc plays an important role in many biochemical reactions within the plants. Zn modifies and/or regulates the activity of carbonic anhydras, an enzyme that regulates the conversion of carbon dioxide to reactive bicarbonate species for fixation to carbohydrates in these plants. Additionally, Zn also, a part of several other enzymes such as superoxide dismutase and catalyze, which prevents oxidative stress in plant cells (Shehata et al., 2009).

Zinc has an important microelement role for the rice crop (Smith & Hamel, 2006) and its deficient may cause significant decrease of the rice yield

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in flooding lands (Hajiboland & Beiramzadeh, 2008). Zinc foliar application can be substituted by soil application of Zn fertilizer in rice and lead to increase in yield of the rice (Rahman et al., 2008). Generally, in paddy lands, the efficiency of using Zn in shoot is more important in relation to the rhizosphere environment (Hafeez et al., 2009 and Nattinee et al., 2009). Zinc deficiency in rice has been widely reported in many rice-growing regions of the world (Fitzgerald et al., 2009; Mandal et al., 2000 and Tiong et al., 2014). Zinc deficiency in crop plants results in not only yield reduction but also Zn malnutrition in humans, where a high proportion of rice is consumed as a staple food (Yao et al., 2012 and Zhang et al., 2009).

Among these, the most important determinant factor in effectiveness of Zn foliar application in the plant is its application time (Maralian, 2009). According to the reports, Zn foliar application (Bandara et al., 2003 and Fageria & Baligar, 2005) resulted in increasing rice grain yield in comparison with control treatment. It has been observed that applying Zn at 45 days after planting has the most correlation with the yield of rice (Slaton et al., 2005). Results of study about investigating different densities of Zn (0.5-1kg per hectare from the source of chelate Zn and sulfate Zn) at different growth stages (tillering and booting stages) which indicated that different doses of fertilizer had significant effect on straw and grain yields of rice, comparing with the control, application of 1kg Zn per hectare from the source of chelate Zn (as partitioning in both stages) had the most grain and straw yield (Maralian, 2009). Increasing Zn concentration of foliar application, significantly increased yield and yield components of rice and maximum seed yield (11.216ton ha^{-1}) was observed in concentration of 1.92g l^{-1}. Where, the negative and significant correlation of empty seed per ear with the grain yield. Also, the time of Zn foliar application was significantly affected in all measured characteristics of rice such that the highest levels of rice yield and yield components were observed when Zn applied at booting stage (Mahmoodi & Mogadam, 2015). On the other hand, zinc deficiency is usually corrected by application of zinc sulfate. The increases in zinc content in grain and straw might be due to the presence of increased amount of Zn in soil solution by the application of zinc that facilitated greater absorption. Increase in Zn content in grain and straw due to zinc fertilization was reported earlier (Mollah et al., 2009 and Fageria et al., 2011). Further, Zn-EDTA proved to be the most efficient source of Zn for rice production.

Application of Zn-EDTA will be helpful to reduce zinc deficiency in rice (Rana & Kashif, 2014). Zinc solution sprayed as a foliar application on rice seedlings three weeks after transplanting was the most effective post transplanting treatment to recover its deficiency (Kumar et al., 1997). Foliar spray could be used effectively to overcome the problem of micronutrients deficiency in sub-soil (Torun et al., 2001). Zinc application methods and timing had significantly pronounced effect on paddy rice yield. Maximum paddy rice yield (5.21tons ha^{-1}) was achieved in treatment Zn (Basal application at the rate of 25kg ha^{-1} 21% $ZnSO_4$) and minimum paddy yield (4.17tons ha^{-1}) was noted in (foliar application of Zn at 75 day after transplanting 0.5% Zn solution) (Mustafa et al., 2011). However, Zn application, significantly increased tillers m^{-2}, total biomass and paddy yield, as well as the Zn concentration in the grain and the straw. In the light of above discussions, present study was designed to investigate the response of rice yield and yield components as well as grain quality to number and levels of zinc foliar spraying application under the agro conditions of Egypt.

Materials and Methods

Two field experiments were conducted during the summer season of 2014 and 2015 growing successive seasons at the Experimental Station of Faculty of Agriculture, Ain Shams University, Shalakan, Kalubia Governorate, Egypt, to investigate the response of rice crop yield and yield components as well as grain quality to the number and levels of zinc foliar spraying application. The soil of the experimental site was clay and its constituents and properties estimated according to Page et al. (1982) are presented in Table 1.

TABLE 1. Soil mechanical and chemical analysis of experimental site at Shalakan.

Mechanical constituents %			Chemical properties							
Fine sand	Silt	Clay	Total N (ppm)	pH	Soluble anions and cations (meq/L)					
					HCO_3^-	Cl^-	Ca^{++}	Mg^{++}	Na^+	K^+
11	31	58	1200	8.0	54.7	44.7	52.6	13.9	38.9	12.7

The experiment included 15 treatments which were the combinations of five zinc (Zn) levels (0, 200, 400, 600 and 800ppm Zn as chelated Zn 14% EDTA) and three foliar application (once (1st spray on 45 DAS), twice (1st spray on 45 DAS and 2nd on 60 DAS) and thrice (1st spray on 45 DAS, 2nd on 60 DAS and 3rd on 75 DAS)). Using backpack sprayer with nozzles oriented vertical spraying of 200L/fad. The experimental design was split plot design with three replications, where the number of zinc foliar application was a located in the main plots and zinc levels distributed in the sub plots. The experimental unit size was 16m^2 (4m×4m). Rice grains, Sakha 104 cultivar, cultivated at the rate of 50kg/fad and were soaked in water for 24h, then drained and incubated for 48h to motivate and enhance germination percentage. Per-germination seeds were manually broadcasted on 1st May in both seasons. In wet leveled plots, 30 day old seedlings were manually transplanted at 20cm between rows × 20cm between hills for obtaining 25hills/m^2. Concerning the chemical fertilizers, the rice crop received 100kg fed^{-1} N as urea, 90kg fed^{-1} of P as P_2O_5 and 60kg fed^{-1} of K as K_2O. Full dose of P and K was applied one day before transplantation, urea was applied in two split application: The first split was applied at 50kg N fed^{-1} one day before transplantation and the second split was applied at 50kg N fed^{-1} after 30 days from transplantation (DAT). All other agronomic practices were uniformly applied as recommended

Data recorded at harvest

At harvest (140 DAS), a sample of plants from one square meter of each experimental unit was collected randomly for measuring number of panicle/m^2, panicle length (cm), number of spikelets/panicle, panicle weight (g), filled grain %, number of filled grain/panicle, 1000 grain weight (g), grain yield (kg/fad), straw yield (kg/fad), biological yield (kg/fad) and harvest index (HI%). Moreover, according to A.O.A.C. (2000), about 50g of grains was fined and grinded to determine nitrogen (N) percentage using micro-Kjeldal method. The grain crude protein content (GCPC) was calculated by multiplying total N% by 5.7, then the grain crude protein yield (GCPY) was computed. The soluble carbohydrate % was determined by acid hydrolysis. The accumulated total nitrogen in grains and straw yields were estimated according to A.O.A.C. (2000) to calculate nitrogen physiological parameters including N recovery efficiency (NRE, kg N absorbed×100/kg N applied/fad), N use efficiency (NUE, grain yield in kg/fad/kg N applied/fad), nitrogen harvest index (NHI, total N in grains×100/total N uptake) and nitrogen physiological efficiency (NPE, grain yield in kg/fad/N absorbed/fad) were calculated according to Timsina et al. (2001).

Statistical analysis

Data were exposed to the proper statistical analysis according to Snedecor & Cochran (1990). Using Costat computer program V 6.303 (2004), the least significant differences (LSD) at 5% level of significance was used to differentiate between means. Data of both growing seasons were subjected to homogeneity variance test for running the combined analysis.

Results and Discussion

Effect of number of zinc foliar spraying application on yield components of rice

Data in Table 2 indicated that yield components of rice were significantly affected by number of zinc foliar application. Panicle length (cm), spikelets numbers/panicle, panicle weight (g), filled grains % and filled grains numbers/panicle of rice were markedly varied being in increasing order with different number of zinc foliar application. Thrice foliar application of zinc shows the highest values of panicle length (25.20cm), spikelets numbers/panicle (137.47), panicle weight (3.24g), filled grains percent (95.67%) and filled grains numbers/panicle (131.69). While, panicle number/m^2 and 1000 grain weight were slightly affected by number of zinc foliar application where, the increment in both characters did not reach to the level of significance. The most important determinant factor in effectiveness of Zn foliar application in the plant is its application time (Maralian, 2009). Kumar et al. (1997) who found that zinc solution sprayed as a foliar application on rice seedlings three weeks after transplanting was the most effective post transplanting treatment to recover its deficiency. Also, the time of Zn foliar application was significantly affected all measured characteristics of rice such that highest levels of rice yield and yield components were observed when Zn applied at booting treatment (Mahmoodi & Mogadam, 2015).

TABLE 2. Effect of number of zinc foliar application on yield components of rice (combined analysis of the two growing seasons).

Foliar application number of zinc	Panicle No./m^2	Panicle length (cm)	Spikelets number/ panicle	Panicle weight (g)	Filled grain%	Filled grain/ No.	1000 grain weight (g)
Once	411.13	23.80	131.87	3.00	93.61	123.52	22.98
Twice	415.20	24.87	136.40	3.21	95.33	130.23	23.54
Thrice	416.20	25.20	137.47	3.24	95.67	131.69	23.67
LSD at 5%	N.S	1.03	0.88	0.08	0.73	1.58	N.S

Effect of zinc levels foliar spraying application on yield components of rice

Data presented in Table 3 indicated that yield component characters of rice were significantly affected by zinc level foliar spraying application. Panicle number/m^2, panicle length (cm), number of spikelets/panicle, panicle weight (g), filled grains %, filled grains number/panicle and 1000 grain weight of rice were markedly varied with different foliar zinc levels 0, 200, 400, 600 and 800ppm zinc (Zn). Foliar application of 600ppm Zn gave the highest values of panicle number/m^2 (470.67), panicle length (26.56cm), number of spikelets/panicle (141.56), panicle weight (3.43g), filled grains % (96.99%), filled grains number/panicle (137.37) and 1000 grain weight (24.56g). Significant enhancement of yield components in increasing order with zinc levels can be credited to 600ppm zinc foliar application, which greatly helps the plant to expose its potential to grow. These increments might be resulted from the important role of zinc in many biochemical reactions within the plants. Zn modifies and/or regulates the activity of carbonic anhydras, an enzyme that regulates the conversion of carbon dioxide to reactive bicarbonate species for fixation to carbohydrates in these plants. Additionally, Zn also, a part of several other enzymes such as superoxide dismutase and catalyze, which prevents oxidative stress in plant cells (Shehata et al., 2009). These results are coincided with those reported by Maralian (2009), Mustafa et al. (2011) and Mahmoodi & Mogadam (2015).

Effect of interaction between number and levels of zinc foliar spraying application on yield components of rice

Data illustrated in Table 4 indicated that interaction between zinc levels and zinc foliar application had significant effect in yield components of rice. Application of thrice zinc foliar application of 600ppm exhibited the highest values of panicle number/m^2 (475.33), panicle length (27.67cm), spikelets numbers/panicle (145.00), panicle weight (3.59g), filled grains % (98.38%), filled grains numbers per panicle (142.65) and 1000 grain weight (24.98g) while, the lowest values for the studied characters recorded by the treatment once zinc foliar application and control treatment.

Effect of number of zinc foliar spraying application on yield characters of rice

Data presented in Table 5 showed that grain yield was significantly affected by number of zinc foliar spraying application. The thrice zinc foliar application was characterized by highest significant yield attributes, which reflected on yield parameters and produced significant maximum grain yield (4120.3kg/fad) and straw yield (4890.70kg/fad). The highest grain yield of rice can be attributed to more panicle weight, length and filled grains % due to thrice foliar application of zinc (Table 2). From the above mentioned data in Tables 2 and 5, it could be concluded that the higher yield attributes, higher grain and straw yields and subsequently higher biological yield (9011.00kg/fad). GCPY was significantly affected by number of zinc foliar application where thrice zinc foliar application produced the highest GCPY (303.91kg/fad). On the other hand, harvest index was slightly affected by number of zinc foliar application to be ranged between 45.57 to 45.71%. It means that increase grain yield was accompanied with increase of straw yield by the same trend. These results are in harmony with those obtained by Slaton et al. (2005) who observed that applying Zn at 45 days after planting, has the most correlation (r =0.89**) with the rice yield.

Effect of zinc levels foliar spraying application on yield of rice

Data in Table 6 indicated that grain, straw and biological yields as well as Grain crude protein content (GCPY) were significantly affected by zinc levels. However, zinc foliar application of 600ppm was characterized by the highest significant yield attributes, which reflected its yield parameters and produced maximum grain yield (4302.90kg/fad) and straw yield (5045.60kg/fad) (Table 6), it can be attributed to more panicle number, weight, length and filled grains %. From the above mentioned data in Tables 3 and 6, it could be concluded that higher yield attributes, higher grain and straw yields and subsequently the higher biological yield. Other researchers reported positive and significant effect of Zn foliar application in increasing yield of the rice too (Fageria & Baligar, 2005; Maralian, 2009; Mustafa et al., 2011 and Mahmoodi & Mogadam, 2015). Zinc is one of the most important microelement for the rice and its deficient may cause significant decrease of the rice yield in flooding lands (Smith & Hamel, 2006).

Grain crude protein content (GCPY) was significantly affected by zinc foliar application where the level of 600ppm zinc foliar application produced the highest GCPY (321.60kg/fad). On the other hand, harvest index was slightly affected by zinc foliar application where its range between 45.06 to 46.06%. It means that increase grain yield was accompanied with increase of straw yield by the same trend. In this condition and according to the achieved results, zinc foliar can be substituted by soil application of Zn fertilizer in rice and lead to increase yield of the rice (Rahman et al., 2008).

TABLE 3. Effect of zinc levels foliar application (ppm) on yield components of rice (combined analysis of the two growing seasons).

Zinc levels (ppm)	Panicle No./m^2	Panicle length (cm)	Spikelets number/panicle	Panicle weight (g)	Filled grain%	Filled grain No./panicle	1000 grain weight (g)
Control	321.33	21.00	123.44	2.74	90.96	112.29	21.63
200	379.89	24.56	134.67	3.01	94.15	126.84	22.93
400	436.00	25.22	138.67	3.18	95.73	132.83	23.72
600	470.67	26.56	141.56	3.43	96.99	137.37	24.56
800	463.00	25.78	137.89	3.39	96.52	133.08	24.14
LSD at 5%	6.01	1.13	4.01	0.07	0.82	4.22	0.82

TABLE 4. Effect of the interaction between number and levels of zinc foliar application on yield components of rice (combined analysis of the two growing seasons).

Treatment		Panicle No./m^2	Panicle length (cm)	Spikelets number/ panicle	Panicle weight (g)	Filled grain%	Filled grain No./ panicle	1000 grain weight (g)
Foliar application number	Zinc ppm							
Once	Control	321.00	20.67	123.00	2.67	90.94	111.86	21.19
	200	373.00	23.67	131.67	2.88	92.78	122.18	22.59
	400	432.67	24.00	132.33	3.01	93.37	123.56	23.09
	600	466.33	25.00	135.00	3.16	94.81	127.99	23.91
	800	462.67	25.67	137.33	3.26	96.13	132.04	24.10
Twice	Control	321.33	21.00	123.33	2.77	90.97	112.21	21.80
	200	383.33	24.67	134.33	3.05	94.19	126.56	22.96
	400	437.33	25.67	141.33	3.23	96.81	136.84	24.02
	600	470.33	27.00	144.67	3.53	97.79	141.48	24.77
	800	463.67	26.00	138.33	3.47	96.91	134.07	24.17
Thrice	Control	321.67	21.33	124.00	2.77	90.98	112.82	21.91
	200	383.33	25.33	138.00	3.11	95.48	131.77	23.24
	400	438.00	26.00	142.33	3.31	97.00	138.08	24.05
	600	475.33	27.67	145.00	3.59	98.38	142.65	24.98
	800	462.67	25.67	138.00	3.43	96.51	133.13	24.14
LSD at 5%		10.41	1.95	6.95	0.11	1.43	7.32	1.43

TABLE 5. Effect of number of zinc foliar application on yield of rice (combined analysis of the two growing seasons).

Foliar application number	Grain yield (kg/fad)	Straw yield (kg/fad)	Biological yield (kg/fad)	GCPY (kg/fad)	HI%
Once	3929.60	4692.70	8622.30	277.78	45.57
Twice	4118.10	4877.60	8995.70	300.96	45.76
Thrice	4120.30	4890.70	9011.00	303.91	45.71
LSD at 5%	49.25	60.88	96.30	4.24	N.S

Grain crude protein content (GCPC) and harvest index (HI).

TABLE 6. Effect of zinc levels foliar application (ppm) on yield of rice (combined analysis of the two growing seasons).

Zinc levels (ppm)	Grain yield (kg/fad)	Straw yield (kg/fad)	Biological yield (kg/fad)	GCPY (kg/fad)	HI%
Control	3677.90	4484.60	8162.40	246.88	45.06
200	3960.10	4734.10	8694.20	283.90	45.55
400	4147.80	4856.60	9004.30	304.49	46.06
600	4302.90	5045.60	9348.40	321.60	46.02
800	4191.40	4980.80	9172.20	314.21	45.69
LSD at 5%	72.68	58.02	99.02	10.59	N.S

Grain crude protein content (GCPC) and harvest index (HI).

Effect of interaction between number and levels of zinc foliar spraying application on yield of rice

Data presented in Table 7 indicated to the effect of interaction between number and levels of zinc foliar application on grain yield, straw yield, biological yield, grain crude protein content (GCPY) and harvest index of rice. Data cleared that maximal values of grain yield (4442.30kg/fad), straw yield (5180.70kg/fad), biological yield (9623.00kg/fad) and GCP yields (337.23kg/fad) were obtained when rice plants spraying with 600ppm for thrice zinc foliar application. On the other hand, harvest index was slightly affected by interaction between number and levels of zinc foliar application, its range between 44.98 to 46.26%. It means that increase grain yield was accompanied with increase of straw yield by the same trend. High performance of rice plants with thrice foliar application of 600ppm Zn in yield attributes was reflected on its yield parameters (Table 4). Zinc solution sprayed as a foliar application on rice seedlings three weeks after transplanting was the most effective post transplanting treatment to recover its deficiency (Kumar et al., 1997). Torun et al. (2001) who found that foliar spray could be used effectively to overcome the problem of micronutrients deficiency in sub-soil. Zinc application methods and timing had significantly pronounced effect on paddy rice yield. Maximum paddy rice yield (5.21tons ha^{-1}) was achieved in treatment Zn (Basal application at the rate of 25kg ha^{-1} 21% $ZnSO_4$) and minimum paddy yield (4.17 tons ha^{-1}) was noted in (foliar application of Zn at 75 day after transplanting 0.5% Zn solution) this data was obtained by Mustafa et al. (2011).

Effect of number of zinc foliar spraying application on nitrogen physiological parameters of rice

Data tabulated in Table 8 indicated that grain and straw nitrogen content were estimated to evaluate nitrogen physiological parameters as affected by foliar application number of zinc. The data of grain nitrogen yield (GNY), straw nitrogen yield (SNY), total nitrogen yield (TNY), nitrogen recovery efficiency (NRE), nitrogen use efficiency (NUE), nitrogen physiological efficiency (NPE) and nitrogen harvest index (NHI) traits were varied considerably depending on number of zinc foliar application. Table 8 shows that thrice of zinc foliar application had the highest values of grain crude protein content (GCPC) (7.36%), soluble carbohydrate (74.30%), GNY (53.32), SNY (6.58), TNY (59.90), NRE (99.83%) and NUE (68.67kg grains/kg nitrogen applied). On the other hand, NPE exhibiting maximum value 72.20kg grains/kg N absorbed with once foliar application of zinc. Concerning NHI, the data in (Table 8) showed slight differences versus studying number of zinc foliar application, its range between 89.03 to 89.28%. It was also found a positive relationship between NUE and NRE%.

Effect of zinc levels foliar spraying application on nitrogen physiological parameters of rice

Data in Table 9 indicated that grain and straw nitrogen contents were estimated to evaluate nitrogen physiological parameters as affected by studied zinc levels foliar spraying application. The data of grain nitrogen yield (GNY), straw nitrogen yield (SNY), total nitrogen yield (TNY), nitrogen recovery efficiency (NRE), nitrogen use efficiency (NUE), nitrogen physiological efficiency (NPE) and nitrogen harvest index (NHI) traits were varied considerably depending on zinc levels foliar spraying application. Table 9 shows that zinc foliar application of 600 ppm had the highest values of grain crude protein content (GCPC) (7.46%), soluble carbohydrate (74.91%), GNY (56.42), SNY (7.02), TNY (63.44), NRE (105.73%) and NUE (71.71kg grains/kg nitrogen applied). On the other hand, NPE exhibiting maximum value 76.02kg grains/kg N absorbed in control treatment. Concerning NHI, the data in Table 9 showed slight differences versus studying zinc levels foliar application, its range between 88.77 to 89.50%. It was also found a positive relationship between NUE and NRE%. No significant differences between 600 and 800ppm zinc levels in most of studied nitrogen physiological parameters expect nitrogen use efficiency (NUE) character. These results resembled to the findings, that application of zinc improve the crop quality reported by (Rana & Kashif, 2014).

Effect of interaction between number and levels of zinc foliar spraying application on nitrogen physiological parameters of rice

Data presented in Table 10 showed the effect of interaction between number and levels of zinc foliar spraying application on nitrogen physiological parameters of rice, however, significant effect on nitrogen physiological parameters were observed. Data in Table 10 cleared that thrice zinc foliar application of 800ppm exhibited maximum value of GCPC (7.62%). While thrice zinc foliar application at the level of 600ppm gave the highest values of soluble carbohydrate (75.59%), GNY (59.16kg/fad), SNY (7.42kg/fad), TNY (66.59kg/fad), NRE (110.98%) and NUE (74.04kg grains/kg nitrogen applied). Concerning NPE, exhibited maximal value 77.27kg grains/kg N absorbed in once foliar application of tap water. On the other hand, NHI showed slight differences versus studying zinc concentrations and foliar application number of zinc to be range between 88.73 to 89.67%. It was also found a positive relationship between NUE and NRE%.

TABLE 7. Effect of interaction between number and levels of zinc foliar application on yield of rice (combined analysis of the two growing seasons).

Treatment: Foliar application number	Treatment: Zn (ppm)	Grain yield (kg/fad)	Straw yield (kg/fad)	Biological yield (kg/fad)	GCPY (kg/fad)	HI%
Once	Control	3664.30	4482.30	8146.70	242.21	44.98
	200	3864.00	4602.30	8466.30	273.19	45.64
	400	3963.00	4697.70	8660.70	282.28	45.76
	600	4043.70	4817.30	8861.00	292.60	45.63
	800	4113.00	4863.70	8976.70	298.61	45.82
Twice	Control	3673.70	4483.00	8156.70	247.97	45.04
	200	3975.70	4778.00	8753.70	284.97	45.42
	400	4219.00	4907.00	9126.00	310.07	46.23
	600	4422.70	5138.70	9561.30	334.97	46.26
	800	4299.70	5081.30	9381.00	326.82	45.83
Thrice	Control	3695.70	4488.30	8184.00	250.47	45.16
	200	4040.70	4822.00	8862.70	293.53	45.59
	400	4261.30	4965.00	9226.30	321.13	46.19
	600	4442.30	5180.70	9623.00	337.23	46.16
	800	4161.70	4997.30	9159.00	317.21	45.43
LSD at 5%		125.88	100.49	171.51	18.35	N.S

Grain crude protein content (GCPC) and harvest index (HI).

TABLE 8. Effect of number of zinc foliar application on nitrogen physiological parameters of rice (combined analysis of the two growing seasons).

Foliar application number	Grain crude protein %	Soluble carbohydrate %	GNY (kg/fad)	SNY (kg/fad)	TNY (kg/fad)	NRE %	NUE	NPE	NHI %
Once	7.06	73.47	48.73	5.86	54.59	90.99	65.49	72.20	89.28
Twice	7.29	74.12	52.80	6.50	59.30	98.83	68.64	69.83	89.07
Thrice	7.36	74.30	53.32	6.58	59.90	99.83	68.67	69.15	89.03
LSD at 5%	0.06	0.47	0.76	0.23	0.79	0.63	0.74	0.53	N.S

Grain nitrogen yield (GNY), straw nitrogen yield (SNY), total nitrogen yield (TNY), grain crude protein content (GCPC), grain crude protein yield (GCPY), nitrogen recovery efficiency (NRE), N use efficiency (NUE), nitrogen harvest index (NHI) and nitrogen physiological efficiency (NPE).

TABLE 9. Effect of zinc levels foliar application (ppm) on nitrogen physiological parameters of rice (combined analysis of the two growing seasons).

Zinc levels (ppm)	Grain crude protein %	Soluble carbohydrate%	GNY (kg/fad)	SNY (kg/fad)	TNY (kg/fad)	NRE%	NUE	NPE	NHI%
Control	6.71	72.51	43.31	5.08	48.40	80.65	61.30	76.02	89.50
200	7.17	73.71	49.81	6.01	55.81	93.02	66.00	71.04	89.25
400	7.34	74.07	53.42	6.48	59.90	99.83	69.13	69.34	89.19
600	7.46	74.91	56.42	7.02	63.44	105.73	71.71	67.99	88.94
800	7.49	74.59	55.12	6.98	62.10	103.50	69.86	67.58	88.77
LSD at 5%	0.19	0.62	1.93	0.39	2.08	3.43	1.11	1.76	N.S

Grain nitrogen yield (GNY), straw nitrogen yield (SNY), total nitrogen yield (TNY), grain crude protein content (GCPC), grain crude protein yield (GCPY), nitrogen recovery efficiency (NRE), N use efficiency (NUE), nitrogen harvest index (NHI) and nitrogen physiological efficiency (NPE).

TABLE 10. Effect of number and levels of zinc foliar application on nitrogen physiological parameters of rice (combined analysis of the two growing seasons).

Treatment		Grain crude protein%	Soluble carbohydrate %	GNY (kg/fad)	SNY (kg/fad)	TNY (kg/fad)	NRE%	NUE	NPE	NHI%
Foliar application number	Zn ppm									
Once	Control	6.61	72.45	42.49	4.93	47.42	79.03	61.07	77.27	89.60
	200	7.07	73.40	47.93	5.53	53.46	89.10	64.40	72.32	89.67
	400	7.12	73.44	49.52	5.95	55.47	92.44	66.05	71.46	89.28
	600	7.23	73.92	51.33	6.26	57.59	95.99	67.39	70.26	89.13
	800	7.26	74.11	52.39	6.65	59.03	98.39	68.55	69.68	88.74
Twice	Control	6.75	72.51	43.50	5.08	48.58	80.97	61.23	75.62	89.54
	200	7.17	73.77	49.99	6.05	56.05	93.42	66.26	71.00	89.19
	400	7.35	74.15	54.40	6.70	61.11	101.84	70.32	69.06	89.03
	600	7.57	75.23	58.77	7.37	66.13	110.22	73.71	66.89	88.86
	800	7.60	74.92	57.34	7.28	64.62	107.70	71.66	66.57	88.73
Thrice	Control	6.78	72.55	43.94	5.24	49.18	81.97	61.59	75.16	89.34
	200	7.26	73.96	51.50	6.43	57.93	96.54	67.34	69.78	88.89
	400	7.54	74.64	56.34	6.79	63.13	105.21	71.02	67.50	89.25
	600	7.59	75.59	59.16	7.42	66.59	110.98	74.04	66.81	88.82
	800	7.62	74.75	55.65	7.00	62.65	104.42	69.36	66.48	88.84
LSD at 5%		0.34	1.08	3.35	0.67	3.61	5.94	1.92	3.04	N.S

Grain nitrogen yield (GNY), straw nitrogen yield (SNY), total nitrogen yield (TNY), grain crude protein content (GCPC), grain crude protein yield (GCPY), nitrogen recovery efficiency (NRE), N use efficiency (NUE), nitrogen harvest index (NHI) and nitrogen physiological efficiency (NPE).

Conclusion

From results of this study, it can be concluded that application of thrice zinc foliar application at the level of 600ppm, on rice exhibited the highest values of grain, straw, biological and GCP yields as well as most of yield attributes and nitrogen physiological parameters.

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استجابة محصول ومكونات وجودة حبوب الأرز لعدد مرات ومستويات الرش الورقي بالزنك

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اِجريت تجربتين حقليتين في موسمي الزراعة 2014 و 2015 في محطة البحوث والتجارب الزراعية بشلقان التابعة لكلية الزراعة جامعة عين شمس وذلك لتفسير وإيضاح اِستجابة محصول ومكونات وجودة حبوب الأرز لعدد مرات ومستويات الرش الورقي بالزنك كالتالي (الأولى بعد 45 والثانية بعد 60 والثالثة بعد 75 يوم من الزراعة) ومستويات الرش بالزنك كالتالي (صفر، 200، 400، 600 و 800 جزء في المليون) وصممت التجربة بتصميم القطع المنشقة مرة واحدة في ثلاث مكررات، حيث وضع عدد مرات الرش بالقطع الرئيسية، ومستويات الرش بالقطع المنشقة، وأوضحت النتائج أن تركيز الزنك 600 جزء في المليون أعطى أعلى قيم لعدد الداليات في المتر المربع، وطول الدالية، وزن الألف حبة ومحتوي البروتين الخام والكربوهيدرات الذائبة، ومحصول النيتروجين للحبوب والقش، والنيتروجين الكلي، وكفاءة معالجة النيتروجين، وكفاءة اِستخدام النيتروجين، أيضًا أوضحت النتائج أن رش النباتات بثلاث مرات بالزنك أعطى أعلى القيم في طول الدالية، وعدد السنيبلات في الدالية، وزن الدالية، ونسبة اِمتلاء الحبوب، وعدد الحبوب الممتلئة لكل دالية، بينما لم يتأثر كل من عدد الداليات في المتر المربع، وزن الألف حبة بعدد مرات الرش الورقي بالزنك. وإيجازًا، تبين أن رش النباتات بثلاث مرات بالزنك بتركيز 600 جزء في المليون أعطى أعلى قيم لمحصول الحبوب والقش، والمحصول البيولوجي ومحصول البروتين الخام للحبوب .