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EFFECT OF TILE DRAIN SPACING AND ZINC FERTILIZATION ON WHEAT CROP RODUCTIVITY IN SALT-AFFECTED SOILS

Rania, M. EL-Samet and Zienab, H. Abd El-Aziz

Drainage Field Res. Department, Soils, Water and Envir. Res. Inst., Agric. Res. Center Egypt.

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ABSTRACT: A field experiment was performed to study the application of a three spaces tile drainage system and fertilizing with zinc on wheat crop productivity grown on salt-affected soil at EL-Serw Agricultural Research Station in Damietta Governorate, Egypt, during two successive winter seasons of 2018/2019 and 2019/2020. The experiment was designed in a split-plot design with three replicates. The results showed that reducing drainage distances to 15 m led to a significant increase of the yield component and NPK and Zn content of wheat plants. likewise, raising zinc fertilization rate to 40 kg ha^{-1} induced a significant enhancement in all studied traits. However, the phosphorus content of grains reduced with increasing zinc fertilization rates, this may be due to the antagonistic effect of Zn on P uptake. The obtained results, appeared that the best treatment applied in this experiment is to utilize a distance of 15 m for the subsurface drainage system with the addition of zinc at a rate of 40 kg ha^{-1} to promoting the productivity of the wheat crop.

Key words: Wheat crop, tile drain spacing, zinc fertilization, salt-affected soil.

INTRODUCTION

Wheat is an important cereal crop and also serves as a staple food for many countries of the world. It is the main source of human plant nutrition and part of daily nutritional requirements in one way or another (FAO, 2013). Promoting the production of strategic crops, especially wheat, is a major goal to meet the increase in local demand for it. It is one of the crops that aims to achieve food security, as it is the main food for most Egyptians and a major source of energy. This is because it contains a large percentage of carbohydrates. Although wheat production has increased in recent years, this increase is not commensurate with the growing population needs (Eldalee *et al.*, 2022). To reduce the gap between production and consumption, Egypt has become the largest importer of wheat in the world (Abdelmageed *et al.*, 2019). As a result, the Egyptian government adopted strategies to intensify wheat production, for example. Increasing wheat productivity per unit area as well as expanding cultivated areas (Mosa *et al.*, 2020 and Elzemrany and Faiyad, 2021).

Subsurface drainage removed excess water from the upper soil layers faster than non-drained ones. Plants in drained fields often develop deeper rooting systems. Also, drainage promotes beneficial soil bacteria activity and improves soil roots bed. Deeper roots mean more nutrients and water can be accessed for plant use. Improved soil tilth also increases soil aeration consequently, increased nutrient availability through bacterial activity (Gardner *et al.*, 1994). Tile drainage is playing an important role in improving the growth and yield of plants and subsequently increased not only nitrogen uptake but also all nutrients. The tile drainage also causes very important changes in nutrients movement which make these nutrients more available for plant growth (EL-Hadidy *et al.*, 2002). Also, they found that the maximum wheat grain and straw yields could be achieved by using tile drainage spacing of 15 m compared with 30 and 60 m spacings. Moukhtar *et al.* (2004) and Mahmoud *et al.* (2016) discovered that plant heights as well as the total yield, straw and grain yield increased significantly with decreasing drain spacing treatments. Rafie (2017) also found that soils with narrow drainage distances were higher than soils with wide drainage distances on wheat yield in terms of plant height, spike length, biological, grain and straw yield and weight of 1000 grains.

*Corresponding author: rania.elsamet@gmail.com

Zinc is an essential plant nutrient required for optimal quality of food crops and can affect crop productivity particularly of the severe deficiency (Broadley *et al.,* 2007). Zinc deficiency is widespread in agricultural soils (Alloway, 2009), reducing the nutritional quality of crops grown in these soils (Bereket *et al.*, 2011). It is estimated that approximately 20% of the world's population is severely affected by insufficient zinc intake, living on a grain-dominated diet with inherently low zinc content, and this figure is closer to 25% in Africa (Wessels and Brown, 2012). Zinc is an important micronutrient for plants. Wherever it plays a very effective role in physiological processes, including growth regulation, metabolism of carbohydrates, regulation of auxin synthesis, chlorophyl synthesis, respiration, glucose formation, protein synthesis, defense mechanisms against disease, maintaining biological membranes and pollen formation (Alloway, 2009 and Rudani *et al.*, 2018). Zinc is also required for the regulation and maintenance of the gene expression required for the tolerance of environmental stresses in plants, such as high light intensity and high temperatures (Cakmak, 2000). The physiological stress caused by Zn deficiency results in the development of abnormalities in plants which are manifested as deficiency symptoms. In cases of severe Zn deficiency, visible symptoms include stunted growth, chlorosis of leaves, small leaves and spikelet sterility. However, the quality of crop products (e. g. Zn and protein contents, size and appearance of fruit) is also adversely affected and plants have increased susceptibility to injury by high light intensity and temperature and to infection by certain fungal diseases.

High pH and electrical conductivity (EC) and the presence of high concentrations of sodium, calcium, magnesium and bicarbonate ions found in salty or sodic soil is responsible for low availability of zinc and the occurrence of zinc deficiency in crops. The soils of saline and sodic are normally found in semi-arid and arid regions (Deckers *et al.,* 1998). Alkaline soil containing sufficient level of zinc (> 1 mg kg^{-1}) may show a decrease in zinc availability to crops due to: (1) Zn affinity towards adsorption/fixation on the clay adsorption sites and (2) the high pH of soil (pH 8.0), which might have helped in the formation of unavailable forms of Zn as hydroxides. Zn has greater affinity for adsorption on clay and also it tends to make unavailable zinc hydroxides due to increased pH (Khattak & Pulford, 1999).

Zinc sulphate is a major source of Zn and sulfur and is being used worldwide (Aye, 2011). It was concluded from experiment that better green gram yield was harvested with more net return when zinc sulphate was applied in soil at the rate of 20 kg ha^{-1} (Usman *et al.,* 2014).

For this purpose, different three tile drain spacings were used to improve the soil properties, as well as adding zinc because of its importance in increasing wheat production.

MATERIALS AND METHODS

Two field experiments were conducted at the Agricultural Research Station in El-Serw, Damietta Governorate, Egypt, for the 2018/2019 and 2019/2020 winter seasons to study the effect of covered drainage distances and zinc addition on wheat crop productivity and element absorption. At the beginning of the experiment, the surface layer of the soil (0-30 cm) was analyzed for some chemical and physical analysis as present in Table (1):

Table 1: Some physical and chemical properties of soil before planting in two seasons.

Drains spacing	Particle size distribution			Texture class	O.M %	$CaCO_3$ %	pH	SAR	EC dSm^{-1}	C.E.C (meq $100g^{-1}$ soil)	Available (mg kg^{-1})			
	Sand%	Silt %	Clay %								N	P	K	Zn
The first season														
15	14.87	21.75	64.43	Clayey	0.99	1.46	8.0	9.3	3.5	43.2	34	9.12	458	1.25
30	13.51	23.10	63.39	Clayey	0.86	2.20	8.2	13.8	4.4	40.1	40	8.76	440	1.12
60	15.00	21.15	63.85	Clayey	0.72	2.69	8.4	15.2	5.5	38.4	45	8.56	429	0.99
The second season														
15	15.79	22.40	661.81	Clayey	1.10	1.78	7.9	11.7	3.25	43.6	37	9.23	469	1.37
30	14.32	21.42	64.26	Clayey	0.88	2.86	8.0	14.5	4.15	40.2	43	8.85	4.54	1.24
60	15.10	21.60	63.30	Clayey	0.79	3.10	8.2	17.1	5.25	38.5	47	8.64	4.36	1.10

The experiment was designed in a split-plot design with three replicates. The main plots were tile drain spacings (15 - 30 - 60 m) and the sub-main plots were zinc fertilization levels (0 - 20 - 40 kg ha^{-1}) in the form of zinc sulphate ($Zn SO_4$. 7 H_2O, 21% Zn) added after 30 days from planting.

The field was prepared by plowing twice and divided into plots of 10.5 m^2 (3 X 3.5 m), then adding the recommended rates of nitrogen, phosphorus and potassium according to the Egyptian Ministry of Agriculture, which are 75: 15: 50 kg / fed^{-1} N: P: K, respectively. Nitrogen fertilizer was added in the form of ammonium nitrate (33.5%) in three doses, the first at planting, the second before the second irrigation and the third before the third irrigation. Phosphorus and potassium were added in the form of superphosphate (15.5% P_2O_5) and potassium sulfate (48% K_2O) with preparing the soil for planting.

In both seasons, wheat grains (*Triticum aestivum L, var misr 1*) obtained from Ministry of Agriculture and Land Reclamation and planted at a rate of 145 kg ha^{-1} in 16 and 20 of November in both seasons, respectively, and harvested at the end of April at maturity, the plants are harvested at 140 days of planting. A sample of wheat plants was taken to record the plant height, length of spike and weight of 1000 grains. The grain yield and straw were recorded per m^2 and then converted to feddan (feddan = 4200 m^2). Biological yield ton ha^{-1} the harvest index was calculated as: the ratio of grain yield to biological yield is given in percentage. Nutritional status of wheat grains: The grains were oven-dried and ground then digested with a mixture of sulfuric and perchloric acids (1:1) according to Chapman and Pratt (1961), then the nutrient content of N, P and K were determined using kjeldahl, Spectrophotometer and flame photometer, respectively, according to Jackson (1967). Zinc is determined using atomic absorption according to Khazaei *et al.* (2017). The protein % = (N%) × 5.75 as described by (Anonymous, 1990).

After harvesting the crop and soil samples were taken, air dried, and analyzed to estimate NPK and Zn and organic matter in the soil. Haluschak (2006) methods were used to determine the mechanical analysis. Reeuwijk (2002) was used to determine the amount of available N, P, K and Zn. Contributing parameters data were recorded and statistically analyzed using CoSTATE computer software according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Wheat yield and its components

1. Plant height, spike length and weight of 1000 grain of wheat

The results of a two-year (Table 2) revealed that the spacing of tile drainage had a highly significant effect on plant height, spike length and weight of 1000 grains. Also, the spacing of 15 m was better than the spacing of 30 and 60 m, as it gave the highest values for the studied characteristics in (Table 2). This may be due to the effect of drainage on improving the physical and chemical properties of the soil, which affects the relationship between water and air in the root zone, and the penetration of the roots, that leads to the more uptake of water and nutrients by plants. These results are consistent with asmelings of (Rafie, 2017).

According to the most effective rate of applied zinc fertilizer to wheat plants, that is shown in Table (2). 40 kg ha^{-1} of applied Zn sulfate achieved the highest increase in plant height, spike length and weight of 1000 grains compared to the control in both seasons. It may be due to the role of zinc in activation of many enzymes in many physiological processes, including chlorophyll synthesis, growth regulation, respiration, defense mechanisms against disease and maintaining biological membranes and thus their importance in achieving higher yield (Alloway, 2009).

A highly significant effect of the interaction between subsurface drainage spacing and the addition of zinc on wheat plants, was observed on plant height, spike length and weight of 1000 grains. All zinc addition rates with the tile drainage spacing treatments increased the abovementioned characteristics. The drainage spacing of 15 m and the zinc level of 40 kg ha^{-1} recorded the highest values for plant height, spike length and weight of 1000 grains during both growing seasons.

Table 2: Effect of tile drainage spacing and application rates of Zn on yield component during 2018-2019 and 2019-2020.

Treatment		Plant height (cm)		Spike length (cm)		1000 grain weight (g)	
		2018 / 2019	2019 / 2020	2018 / 2019	2019 / 2020	2018 / 2019	2019 / 2020
Drainage spacing (m)							
60		83.28	85.36	10.24	11.27	40.64	40.87
30		87.84	89.94	13.63	14.98	45.17	45.22
15		91.28	93.48	14.92	16.01	47.61	48.16
F. Test		***	***	***	***	***	***
LSD% at 5%		0.17	0.17	0.22	0.30	0.13	0.07
Zn level (kg ha^{-1})							
0		84.28	86.31	11.27	12.18	42.79	43.07
20		87.60	89.63	12.94	13.96	44.57	45.00
40		90.80	92.83	14.59	16.13	46.07	46.07
F. Test		***	***	***	***	***	***
LSD% at 5%		0.30	0.30	0.22	0.17	0.22	0.07
Interaction							
60	0	81.70	83.5	9.63	1047	39.71	39.92
	20	83.37	85.17	10.30	11.3	40.65	40.85
	40	85.60	87.40	10.80	12.03	41.57	41.85
30	0	84.80	86.90	11.63	12.57	43.48	43.97
	20	87.53	89.63	13.80	14.77	45.23	45.31
	40	91.20	93.30	15.47	17.63	46.81	46.37
15	0	86.33	88.53	12.53	13.50	45.18	45.65
	20	91.90	91.10	14.73	15.80	47.82	48.85
	40	95.60	97.80	17.50	18.73	49.84	49.99
F. Test		***	***	***	***	***	***
LSD% at 5%		0.32	0.32	0.23	0.18	0.18	0.07

2. Grain yield, straw yield, biological yield ton ha^{-1} and harvest index of wheat

The yield of straw, grains and biological ton ha^{-1} and the harvest index % are presented in Table (3) showed that there were a highly significant differences between the effect of subsurface drainage distances, where the distance of 15 m gave the highest values for the studied measurements compared to the distance of 30 and 60 m. The increase in the studied components may be ascribed to the impact of tile drainage spacing of 15 m, that improve soil properties consequently stimulate the activity of microorganisms in the soil likewise, enhance root extension and its nutrients uptake. These results are in consequently with that obtained by Mokhtar *et al.* (2004) and Schott *et al.* (2017).

It was noted that there is a significant difference many the influence of added Zn rates on crop characteristics (Table 3). The highest values were observed at a rate of 40 kg ha^{-1} and the lowest values were with the absence of zinc fertilization. These results are in agreement with that obtained by Firdous *et al.* (2018). Ram *et al.* (2012) denoted that adding Zn to soil had a long-term impact on increasing crop productivity in Zn-deficient soils. The effect of Zinc may be attributed to its physiological influence on a number of enzymes such as carbonic anhydrogenase and formation of growth hormones such as auxin, promotes starch formation and seed ripening. Which reflect on promoting that the productivity of wheat grains and straw.

The statistical analysis of the data in Table (3) shows the effect of the interaction between the coefficients of the drainage distances covered under the presence and absence of zinc fertilization. The current study indicated that the application of tile drainage distances with Zn application, induced a significant increase in grain, straw and biological yield ton ha^{-1} and the harvest index %. In this regard, the highest average values of determined components were achieved with the application of a drainage distance of 15 m, followed by a distance of 30 m, then 60 m in the presence of Zn compared to the control received no Zn fertilizer.

Table 3: Effect of tile drainage spacing and application different rates of Zn fertilization on grain, straw and biological yield ton ha^{-1} and harvest index% of wheat during two seasons.

Treatment		Straw yield (t ha^{-1})		Grain yield (t ha^{-1})		Biological yield (t ha^{-1})		Harvest index %	
		2018 / 2019	2019 /2020	2018 / 2019	2019 / 2020	2018 / 2019	2019 / 2020	2018 / 2019	2019 / 2020
Drainage spacing (m)									
60		6.02	6.22	3.94	4.05	6.96	10.27	39.55	39.43
30		6.53	6.84	4.46	4.62	10.99	11.46	40.57	40.29
15		6.73	7.28	4.74	5.00	11.46	12.28	41.32	40.67
F. Test		***	***	***	***	***	***	***	***
LSD% at 5%		0.004	0.03	0.05	0.05	0.05	0.06	0.30	0.26
Zn level (kg ha^{-1})									
0		6.02	6.38	4.06	4.20	10.09	10.57	40.19	39.66
20		6.53	6.75	4.30	4.49	10.61	11.24	40.54	39.94
40		6.73	7.22	4.78	4.98	11.71	12.20	40.71	40.80
F. Test		***	***	***	***	***	***	***	***
LSD% at 5%		0.03	0.03	0.02	0.01	0.04	0.03	0.14	0.09
Interaction									
60	0	5.69	5.85	3.69	3.71	9.39	9.56	39.35	38.82
	20	6.02	6.23	3.94	4.02	9.96	10.25	39.61	39.20
	40	6.36	6.58	4.18	4.44	10.54	11.01	39.69	40.29
30	0	6.06	6.41	4.04	4.25	10.10	10.66	40.02	39.89
	20	6.38	6.74	4.37	4.52	10.75	11.25	40.67	40.14
	40	7.15	7.37	4.97	5.09	12.12	12.46	41.02	40.84
15	0	6.34	6.87	4.44	4.63	10.78	11.50	41.21	40.26
	20	6.52	7.27	4.59	4.95	11.11	12.22	41.33	40.49
	40	7.32	7.71	5.18	5.42	12.49	13.13	41.44	41.26
F. Test		***	***	***	***	***	***	**	**
LSD% at 5%		0.01	0.03	0.03	0.02	0.04	0.04	0.14	0.10

3. Nutrient content and protein % of wheat grains

The nutritional content of wheat grains, such as N, P, K%, Zn ppm and protein % affected by the spacing between tile drain spacing, addition of different rates of zinc to the soil and their interaction are shown in Table 4 during the two growing seasons.

The obtained data presented in Table 4 appeared that the percentage of nitrogen, phosphorus, potassium, protein and zinc ppm in wheat grains was highly significant affected by the tile drainage distance of 15, 30 and 60 m in both seasons. It has also been displayed that element concentrations increase with decreasing subsurface drainage distances. This may be due to the tile drainage spacing of 15 m which cause an improve in soil properties consequently, nutrients availability and its uptake by plants. These results are similar to that obtained by Abdel-Khalik (2000) and EL-Hadidy *et al.* (2002).

Table 4: Effect of tile drainage spacing and application different rates of Zn fertilization on N, P, K, Zn content and protein % of grain wheat during two seasons.

Treatment		N%		P%		K%		Zn ppm		Protein %	
		2018 / 2019	2019 / 2020	2018 / 2019	2019 / 2020	2018 / 2019	2019 / 2020	2018 / 2019	2019 / 2020	2018 / 2019	2019 / 2020
Drainage spacing (m)											
60		1.75	1.77	0.150	0.161	1.57	1.66	31.31	33.27	10.08	10.16
30		1.88	1.93	0.172	0.184	1.76	1.87	35.42	37.68	10.80	11.10
15		1.99	2.2	0.190	0.201	1.95	2.09	41.03	42.61	11.47	11.61
F. Test		***	***	***	***	***	***	***	***	***	***
LSD% at 5%		0.03	0.05	0.003	0.001	0.03	0.02	0.04	0.05	0.15	0.26
Zn level (kg ha^{-1})											
0		1.77	1.77	0.187	0.199	1.58	1.67	32.58	34.07	10.21	10.19
20		1.88	1.93	0.154	0.164	1.77	1.89	36.27	38.96	10.84	11.10
40		1.97	2.01	0.171	0.184	1.94	2.07	38.92	40.80	11.3	11.58
F. Test		***	***	***	***	***	***	***	***	***	***
LSD% at 5%		0.02	0.03	0.002	0.002	0.018	0.02	0.06	0.07	0.12	0.17
Interaction											
60	0	1.62	1.67	0.164	0.177	1.44	1.51	29.81	30.23	9.3	9.58
	20	1.77	1.79	0.137	0.145	1.56	1.65	31.05	33.96	10.18	10.27
	40	1.87	1.85	0.148	0.162	1.72	1.83	33.08	35.62	10.75	10.62
30	0	1.78	1.79	0.189	0.203	1.54	1.62	32.20	33.76	10.24	10.31
	20	1.88	1.96	0.152	0.163	1.77	1.89	36.37	38.19	10.83	11.25
	40	1.97	2.04	0.176	0.186	1.97	2.09	38.69	41.09	11.33	11.73
15	0	1.93	1.85	0.207	0.217	1.75	1.88	36.74	38.21	11.08	10.66
	20	2	2.05	0.173	0.182	1.97	2.12	41.38	43.93	11.5	11.79
	40	2.06	2.15	0.190	0.204	2.14	2.28	44.98	45.68	11.83	12.38
F. Test		**	*	**	Ns	***	***	***	***	**	*
LSD% at 5%		0.02	0.03	0.002	0.003	0.019	0.02	0.07	0.07	0.13	0.18

Data in Table 4, obviously declared the positive influence of tile drainage distance and Zn application individually or its interaction on NPK and Zn concentrations of wheat grains. wherever, the highest values of the abovementioned nutrient content were achieved with 15 m drainage distance and 40 kg Zn ha^{-1} application compared to the control. The increase in the N, K and Zn content can be attributed to the synergistic effect of Zn on the uptake both N and K by plant roots. Current results support the results of Morshedi and Farahbakhsh (2010), Keram *et al.* (2012) and Arab *et al.* (2018).A decrease in P content was observed with the increase in the Zn application levels compared to control. This may be due to the antagonistic effect of Zn on P uptake. It was found that the Zn prohibits the transfer of P from roots to tops of the plant. A similar finding also reported by Alam *et al.* (2000).

Significant variation was found for the interaction effect between tile drainage spacing and application of zinc levels on N, K, Zn contents and protein % in grains wheat (Table 4) with the exception of P content. The highest concentration values of N, K, protein% and Zn ppm were obtained from the combination treatments of spacing 15 m with 40 kg Zn ha^{-1} however, the lowest one was observed with the combination of spacing 60 m with 0 Zn addition (control). The highest concentration of P values was obtained with the combination treatments of spacing 15 m with control and the lowest one was occurred with the combination treatments of spacing 60 m with 20 kg Zn ha^{-1}.

The augmenting effect of Zn application on NPK and protein content may be ascribed to that zinc is essential for RNA polymerase activity and protects ribosomal RNA from the enzyme ribonuclease attack. On the other hand, the meristematic tissues cell division require relatively high concentrations of zinc, DNA and protein synthesis. The primary effect of zinc on protein metabolism is through its involvement in the stability and function of genetic material (Alloway, 2009 and Rudani *et al.*, 2018).

Conclusion

The results which ought to be mentioned herein that the treatment of drainage at a distance of 15 m with the addition of zinc at a rate of 40 kg ha^{-1} achieved the highest values of yield components and nutrients content of wheat plant. However, expanding the tile drainage spacing (30 m) while adding zinc at a rate of 40 kg ha^{-1} gives satisfactory results in increasing wheat yield, and this from the economical point of view will reduce the costs of constructing the drainage.

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تأثير مسافات الصرف المغطي والتسميد بالزنك على إنتاجية محصول القمح في الأراضي المتأثرة بالأملاح

رانيا محمد الصامت إبراهيم ، زينب حمدان عبد العزيز
قسم بحوث الصرف الحقلي، معهد بحوث الأراضي والمياة والبيئة، الجيز، مصر.

الملخص العربى

تم إجراء تجربة ميدانية لدراسة تأثير استخدام ثلاث مسافات لنظام الصرف المغطي والتسميد بالزنك على إنتاجية محصول القمح تحت ظروف الأراضي المتأثرة بالأملاح بمحطة البحوث الزراعية بالسرو بمحافظة دمياط بمصر في موسمي ٢٠١٩/٢٠١٨ و٢٠٢٠/٢٠١٩. تم تصميم التجربة في تصميم القطع المنشقة وتم تكرارها ثلاث مرات. وأظهرت النتائج أن تقليل مسافات الصرف الي ١٥ م أدت إلي زيادة معنوية في الصفات المدروسة. ومن ناحية أخري أدت زيادة التسميد بالزنك بمعدل ٤٠ كجم / هكتار إلي زيادة معنوية لكل الصفات المدروسة ماعدا محتوي الحبوب من الفوسفور قل مع زيادة معدلات التسميد بالزنك، وقد يكون هذا بسبب التأثير المضاد للزنك على امتصاص الفسفور. يمكن القول من خلال النتائج المتحصل عليها ان أفضل معاملة هي استخدام مسافة ١٥ م بين حقليات الصرف المغطي مع إضافة الزنك بمعدل ٤٠ كجم /هكتار لتعظيم إنتاجية محصول القمح.