

EFFECT OF ZINC AND PHOSPHORUS FERTILIZATION ON RICE CROP UNDER SALINE SOIL CONDITIONS

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ABSTRACT

Two field experiments were conducted at the Experimental Farm of El-Sirw Agricultural Research Station, Damietta Governorate, Egypt, in 2007 and 2008 seasons, to study the effect of phosphorus rate (0, 18, 36, and 54 kg P₂O₅/ha) and Zinc rate (0, 12, 24 and 36 kg ZnSO₄/ha) on productivity of some rice cultivars (Giza177, Giza 178 and Sakha104 as inbred cultivars and hybrid cultivar SK2034H) under saline soil conditions.

The hybrid rice cultivar SK2034H was superior to other cultivars in leaf area index, dry matter production (g/m²), number of tillers/m², number of panicles/m², panicle length, number of filled grains/panicle, grain yield, straw yield, harvest index and nitrogen, phosphorus and protein content of grains in both seasons and plant height only in the second season. However, Giza 177 gave the heaviest 1000-grain weight.

Increasing phosphorus rate from 0 to 36 kg P₂O₅/ha significantly increased leaf area index, number of tillers/m², number of panicles/m², panicle length, panicle weight, number of filled grains/panicle, grain yield and harvest index in the two seasons. However, the highest dry weight/m², 1000-grain weight, straw yield and N, P and crude protein contents of grains was obtained from application of 54 kg P₂O₅/ha. There were no significant differences in plant height among phosphorus rates in the two seasons of study.

Increasing zinc rate from 0 to 36 kg ZnSO₄/ha significantly increased leaf area index, dry matter production, panicle length, panicle weight, 1000-grain weight, grain yield, straw yield, harvest index and N and crude protein contents of grains. The inverse was true in unfilled grains % and phosphorus content of grains. Application of 24 and 36 kg ZnSO₄/ha, being insignificant, increased number of tillers/m², number of panicles/m² and number of filled grains/panicle compared with control (without zinc fertilizer). Zinc fertilizer rate had no significant effect on plant height in both seasons.

All the first and second order interaction had significant effects on grain yield/ha. The maximum grain yield was obtained from the hybrid cultivar SK2034H fertilized by 54 kg P₂O₅ + 36 kg ZnSO₄/ha or 36 kg P₂O₅ + 24 kg ZnSO₄/ha in the two seasons. The highest grain yield of Giza 178 and Sakha104 were obtained by application of 36 kg P₂O₅ and 36 kg ZnSO₄/ha.

It can be concluded that sowing SK2034H rice cultivar and application phosphorus fertilizer at the rate of 54 kg P₂O₅ /ha and Zinc fertilizer at the rate of 24 or 36 kg ZnSO₄ could be recommended to produce optimum grain yield per unit area under saline soil condition.

INTRODUCTION

Rice ability to grow on saline soils is justified by world practice. Many researchers consider rice to be a crop with medium salt resistance. But since water layer reduces salt concentration, plant growth is not inhibited. Soil

salinity causes adverse effects on different physiological processes, which are responsible for reduction of growth of plants (Ashraf, 2004 and Munns *et al.*, 2006). So, increasing salt tolerance of crops is necessary to sustain food production in different saline regions (Pitman and Lauchli, 2002). Selection of the suitable rice variety is the first prerequisite for a good yield. The salt tolerance of rice variety is a key factor influencing crop yield and quality under saline soils conditions. Zayed *et al.* (2006) recorded varietal difference in growth, grain yield and its components under saline soil conditions. Gautam (2004) obtained a significantly better growth performance from hybrids than conventional varieties, particularly in LAI, dry matter (at heading and grain filling) plant height and panicle length. In addition, Gautam (2004) and Abou Khalifa (2005) emphasized superiority of rice hybrid over inbred ones in panicles number/plant, filled grains/panicle, fertility percentage, panicle weight, 1000-grain weight, harvest index as well as straw and grain yields. On the other hand, Zayed *et al.* (2007), Alam *et al.* (2009) and Zayed *et al.* (2010) recognized variation between inbred rice and hybrid varieties regarding growth, grain yields and its attributing characteristics under normal and saline soils.

Sodic soils have high concentrations of free carbonate and bicarbonate and excess of sodium on the exchangeable site of clay particles. They are deficient in nitrogen, phosphorus and zinc. Supplementary phosphorus has a role in alleviation of the adverse effects of high salinity on whole plant biomass for a variety of crop plants (Kaya *et al.*, 2003). Wilson *et al.* (1999) stated that phosphorous uptake and content was decreased as pH value increased beyond 7 and phosphorous application significantly increased rice grain yield and P tissue content. Panda *et al.* (1995) and Heluf and Seyoum (2006) reported that increased dry matter production including grain yield and yield attributing characters of rice (number of panicles/m², number of spikelets/panicle⁻¹, panicle length, dry matter accumulation, plant height and straw yield) due to P uptake in response to external supply of P fertilizers. Ali and Ansari (2006) indicated that under high sodicity, increasing phosphorous level significantly increased dry matter, LAI, chlorophyll content, panicles number, filled grains, panicle weight grain and straw yields as result of increasing rice salt tolerance and reducing Na uptake. Alam *et al.* (2009) reported that rice growth parameters, grain yield, straw yield and harvest index as well as yield attributing characteristics significantly increased by phosphorous application up to 72 kg P₂O₅ ha⁻¹, and beyond this level these traits started to decrease.

Zinc plays an important role in many biochemical reactions within different plants. Zinc modifies and/or regulates the activity of carbonic anhydrase and enzyme that regulates the conversion of carbon dioxide to reactive bicarbonate species for fixation to carbohydrates in these plants. Zinc is also a part of several other enzymes such as superoxide dismutase and catalase, which prevents oxidative stress in plant cells. Shehata *et al.* (2009), under saline soil condition, found that zinc fertilizer had a positive effect on rice growth traits, i.e. dry matter production, leaf area index and yield attributes, i.e. panicle number/hill, plant height, panicle length, panicle weight, filled grains/panicle, 1000-grain weight, straw and grain yields. Also, Bharat

(2006), under saline sodice conditions, recognized that zinc application significantly increased grain and straw yields and harvest index. Many previous investigators reported that increasing zinc rate increased grain yield and its attributes (Ghose *et al.*,1999; Rao and Shukla, 1999; Zia *et al.*, 2000; Hussain, 2004; Tariq *et al.*, 2007 and Khan *et al.*,2009). Malavolta *et al.* (2002) found that foliar spraying with zinc solution increased rice grain yield.

Therefore, The main objective of this attempt is to select the best salt tolerant cultivar and its suitable fertilizer (phosphorous and zinc rates), which could produce satisfactory yield under saline soil conditions.

MATERIALS AND METHODS

Two field experiments were conducted at the Experimental Farm of El-Sirw Agricultural Research Station, Damietta Governorate, Egypt, in 2007 and 2008 seasons, to study the effect of phosphorus and Zinc fertilizer on growth, yield, yield components and some grain quality of some rice cultivars under saline soil conditions. The previous crop was Egyptian clover (*Trifolium alexandrinum*,L) in both seasons. Representative soil samples were taken from each site at the depth of 0-30 cm from the soil surface. Samples were air-dried then ground to pass through a two mm sieve and well mixed. The procedure of soil analysis followed the methods of Black *et al.* (1965). Results of chemical analysis in both seasons are shown in Table 1. Phosphorus fertilizer in the form of calcium super phosphate (15.5% P₂O₅) were applied at the four rates of 0, 18, 36, and 54 KgP₂O₅/ha as basal application on the dry soil and incorporated with soil during land preparation. The experimental soils were divided into four parts before plowing. Each part was located to each phosphorus rate as independent experiment. The experimental design was a split-plot with three replicates in each phosphorus rate in both seasons. Main plots were assigned to rice cultivars, sub plots to zinc rate.

Table 1: Some chemical properties of the soil in the experimental sites

Character	2007 season	2008 season
Texture	Clay	Clay
PH (2.5:1)	8.6	8.2
EC (dS.m ⁻¹)	8n	7.5
OM (%)	1.5	1.56
Ca ⁺⁺ (meq. L ⁻¹)	7.8	6.8
Mg ⁺⁺ (meq. L ⁻¹)	5.40	8.4
K ⁺ (meq. L ⁻¹)	0.50	0.70
Na ⁺ (meq. L ⁻¹)	70.0	69.0
CO ₃ ⁻ (meq. L ⁻¹)	-	-
HCO ₃ ⁻ (meq. L ⁻¹)	9.64	8.64
CL ⁻ (meq. L ⁻¹)	71.5	64.6
SO ₄ ⁻ (meq. L ⁻¹)	6.33	5.33
Available Fe (ppm)	5.23	5.95
Available Zn (ppm)	0.90	0.71
Available Mn (ppm)	4.50	4.50

Four rice cultivars consisted of three inbred cultivars, namely Giza177, Giza 178 and Sakha104 as well as one hybrid cultivar, namely Sk2034H were used. Zinc sulfate was applied with the four rates of 0, 12, 24 and 36 kg ZnSO₄/ha after wet leveling. A combined analysis was used among phosphorus rates in each season. The plot size was 10.8 m² (3 × 3.6 m) in all experiments. In each plot, an area of 2.16 m² (0.6 × 3.6 m) was devoted for plant growth sampling and 8.64 m² (2.4 × 3.6 m) for determining grain yield and its attributes. Every plot consists of 15 rows and the distance between the hills and the rows was 20×20 cm for Giza 178, Sakha104 and SK2034H cultivars. However, every plot consists of 20 rows and the distance between the hills and rows was 15×15 cm for Giza 177 cultivar.

The seed of each inbred rice cultivar at the rate of 144 kg seed/ha and hybrid cultivar at the rate of 35 kg seed/ ha were soaked in water for 36 hours then drained and incubated for 48 hours to hasten early germination. Pre-germinated seeds were uniformly broadcast in the nursery on May 15th, in 2007 and 2008 seasons. The zinc and phosphorus fertilizers did not apply in the nursery. The other cultural practices were applied as recommended. The permanent field was identified and well prepared. Seedlings were carefully pulled from nursery after 30 days and transferred to the permanent field. Seedlings were handling transplanted in hills at the rate of 3-4 seedlings/hill. At the spacing of 20X20 cm between hills and rows for all cultivar except the cultivar Giza177 where the spacing were 15X15 cm. Nitrogen in from of urea (46%N) at rate of 165 kg/ha was applied in three equal doses. The first dose was applied and ported in the dry soil before flooding, the second and third at 15 and 35 days after transplanting. The other usual agricultural practices of growing rice were performed as the recommendations of Ministry of Agriculture and Land Reclamation. Plant sample (five hills each) were taken randomly from each plot at heading to estimate the plant height (cm), leaf area, dry matter g/m² and number of tillers/m². Leaf area (blade area) was measured by portable area meter (Model LI-3000A). Then LAI was calculated (dividing Leaf area per hill /ground area/hill). At harvesting number of panicles/m² were counted. Ten panicles were collected randomly to estimate the panicle weight, panicle length, number of filled grains and unfilled grains/panicle and 1000-grain weight. The total weight of both grain and straw was recorded. The weight of grains was adjusted to 14% moisture content. Samples were taken from grain and straw at harvest to determine N and P contents. All samples were oven dried to a constant weight at 70°C, then ground to powder and digested according the method of Chapman and Pratt (1961). Total N was determined by MicroKjeldahl method (Blak *et al.*,1965) and P calorimetrically by ascorbic acid according to Watanabe and Olsen (1965).Nitrogen content in rice grains was multiplied by factor of 5.95 to estimate the crude protein content in rice grains.

The analysis of variance was carried out as a combined analysis for the four sowing dates in each season according to Gomez and Gomez (1984). Treatment means were compared by Duncan's Multiple Range Test (Duncan, 1955). All statistical analysis was performed using analysis of variance technique by means of "MSTATC" computer software package.

RESULTS AND DISCUSSION

A- Growth:

Leaf area index (LAI), plant height, dry matter accumulation and tillers number of some rice cultivars at heading as affected by phosphors, zinc rates and their interaction in 2007 and 2008 seasons are presented in Table 2.

1. Rice cultivars performance:

Rice cultivars varied significantly in all mentioned growth traits in both seasons, except plant height in the first season. The hybrid rice cultivar SK2034H was significantly superior to the other cultivars in LAI, dry weight/m² and tillers number/m² in the two seasons. The minimum values of the mentioned traits were recorded by the salt sensitive cultivar Giza177 in both seasons. Giza 178 came in the second order in this respect. The superiority of SK2034H cultivar could be attributed to more number of tillers and leaves resulted in large photosynthetic area (leaf area), which resulted in more photosynthetic production and consequently increased dry matter accumulation. The varietal differences in LAI are reflected different genetic make up. The current findings are in agreement with those reported by Alam *et al* (2009) and Zayed *et al* (2010), who revealed that hybrid rice surpassed inbred rice varieties in LAI, dry matter and number of tillers.

2. Effect of phosphorus rate:

Application of phosphorus fertilizer resulted in a significant increase in LAI, dry weight/m² and number of tillers/m² compared with control (without phosphorus fertilizer). However, phosphorus rate had no significant effect on plant height. LAI was significantly increased by increasing phosphorus rate from 0 to 36 kg P₂O₅/ha and then it was decreased in both seasons.

Increasing phosphorus rate from 0 up to 54 kg P₂O₅/ha gradually increased dry matter production in both seasons. The relative ranking of phosphorus rates for number of tillers was inconsistent in the two seasons. Plants received 36 or 54 kg P₂O₅/ha were among those having great number of tillers/m² in both seasons. No significant difference in number of tillers/m² was observed between the two higher rates of phosphorus in the two seasons. Phosphorus application ameliorated the unfavorable effect of salinity resulted in improving plant growth and in turn increased tillers numbers, LAI and dry matter accumulation. Also, phosphorus application might be increasing phosphorus availability and subsequently increased its uptake and its content in rice plants leading to more ATP formation, that is the main source for energy in plant and might encourage rice growth, metabolism, photosynthesis and nucleic acid resulted in high efficiency of dry matter production. The results are in agreement with those reported by Suriya-arunroj *et al* (2000), Kumar and Singh (2001), Biswas and Dravid (2001), Hood (2002), Ali *et al* (2004), Bharat (2006) and Zayed *et al* (2010).

Table 2: Leaf area index, dry matter accumulation, plant height and tillers number of some rice cultivars as affected by phosphors, zinc rates and their interaction in 2007 and 2008 seasons.

Factor	Leaf area index		Dry weight (g/m ²)		Plant height (cm)		Tillers (No. m ⁻²)	
	2007	2008	2007	2008	2007	2008	2007	2008
Cultivar (C):								
Giza 177	2.79d	2.72d	525.4d	513.1b	91.23	81.66b	342 d	335 c
Giza 178	4.36b	4.23b	792.8b	783.1a	92.13	85.61ab	402 b	418 b
Sakha104	3.98c	3.86c	617.1c	602.9b	94.13	86.99a	370 c	409 b
SK2034H	5.38a	5.32a	847.3a	835.2a	90.93	89.60a	451 a	457 a
F test	*	**	**	**	NS	*	**	**
Kg P₂O₅/ha (P):								
0	3.60d	3.50d	633.0d	604.0d	91.1	85.6	365 c	368 c
18	4.11c	4.01c	679.3c	650.3c	92.9	85.78	384 b	399 b
36	4.55a	4.45a	724.1b	711.9b	92.55	86.09	412 a	432 a
54	4.26b	4.18b	746.2a	768.0a	91.85	86.4	414 a	421 ab
F test	**	**	**	**	NS	NS	**	**
Kg Zn SO₄/ha (Z):								
0	3.46d	3.50d	633.0d	615.8d	91.1	82.79	361 c	358 c
12	3.95c	3.77c	679.3c	665.8c	92.9	86.50	388 b	403 b
24	4.46b	4.30b	724.1b	714.9b	92.55	87.57	408 a	430 a
36	4.65a	4.56a	746.2a	737.9a	91.85	86.99	407 a	428 a
F test	**	**	**	*	NS	NS	**	**
Interaction:								
C X P	*	NS	NS	NS	NS	NS	NS	NS
C X Z	**	NS	NS	NS	NS	NS	NS	NS
P X Z	**	NS	NS	NS	NS	NS	NS	NS
P X Z X C	NS	NS	NS	NS	NS	NS	NS	NS

*, ** and NS indicate $P < 0.05$, $P < 0.01$ and not significant, respectively. Means of each factor designated by the same letter are not significantly different at 5% level using Duncan's MRT.

3. Effect of zinc rate:

LAI, dry weight/m² and number of tillers/m² were substantially increased by application of zinc fertilizer compared with control (without zinc fertilizer) in the two seasons. Plant height was not significantly affected by zinc rate in both seasons. Data in Table 2 reveal that progressive significant increase in LAI and dry weight/m² were recorded with each increment of applied zinc.

Application of zinc with the rates of 24 or 36 kg ZnSO₄/ha produced greater number of tillers than the rate of 12 kg ZnSO₄/ha in the two seasons. There was no significant difference between the two higher rates of 24 or 36 kg ZnSO₄/ha in number of tillers/ m² in both seasons. Results indicate that zinc supply had a controlling influence on LAI, primarily through its effect on tillers number and thus leaf production and expansion. Zinc has a vital role in improve rice growth, where it works as co-enzyme and as activators and enhanced amino acid formation, subsequently increased photosynthesis leading to high dry matter production. The present results are in a good harmony with those claimed by Coutinho *et al* (1992), Biswas and Dravid (2001), Hood (2002) and Shehata *et al*(2009).

4. Effect of interaction:

All the first order interaction had a significant effect on LAI only in the first season. However, none of the interaction had a significant effect on dry weight/m², plant height and number of tillers/m² in both seasons.

B. Yield and its attributes:

Number of panicle/m², panicle length, panicle weight, number of filled grains/panicle, unfilled grains%, 1000-grain weight, grain yield (t/ha), straw yield (t/ha) and harvest index of some rice cultivars as affected by phosphors and zinc rates and their interaction are presented in Tables 3, 4 and 5.

1. Rice cultivars performance:

Rice cultivars exhibited significant differences in all yield attributes in both seasons. The hybrid rice cultivar SK2034H was significantly superior to the other cultivars in panicle number/m², panicle length, panicle weight, number of filled grains/panicle, grain yield (t/ha), straw yield (t/ha) and harvest index. Giza 178 came in the second order after SK2034H in the most of these traits. However, the cultivar Giza177 was inferior to all other cultivars in these respects. The inverse was true in 1000-grain weight and unfilled grains %, where Giza177 recorded the highest values in the two traits in both seasons.

Table 3: Number of panicles, panicle length and panicle weight of some rice cultivars as affected by phosphors and zinc rates and their interaction in 2007 and 2008 seasons.

Factor	Panicles (No. m ⁻²)		Panicle length(cm)		Panicle weight (g)	
	2007	2008	2007	2008	2007	2008
Cultivar (C):						
Giza 177	303 d	294 c	19.48c	19.28d	2.24c	2.38c
Giza 178	359 b	371 b	20.29b	20.41b	2.71b	2.78b
Sakha104	341 c	369 b	19.85c	19.95c	2.63b	2.74b
SK2034H	414 a	424 a	21.00a	20.51a	3.11a	3.23a
F test	**	**	**	**	**	**
Kg P₂O₅/ha (P):						
0	303 c	329 c	19.41d	19.52d	2.33d	2.46c
18	348 b	359 b	20.03c	19.99c	2.65c	2.75b
36	386 a	391 a	20.78a	20.59a	2.94a	3.00a
54	381 a	378 ab	20.40b	20.41b	2.76b	2.92a
F test	**	**	**	**	*	**
Kg Zn SO₄/ha (Z):						
0	325 b	333 c	19.16d	19.35d	2.35c	2.45c
12	353 a	356 b	20.00c	19.92c	2.63b	2.77b
24	375 a	386 a	20.54b	20.44b	2.85a	2.95a
36	365 a	382 ab	20.93a	20.81a	2.86a	2.96a
F test	**	*	**	*	**	**
Interaction:						
C X P	**	**	NS	**	**	**
C X Z	*	**	NS	**	**	**
P X Z	**	*	**	**	*	*
P X Z X C	*	**	NS	NS	NS	NS

*, ** and NS indicate P < 0.05, P < 0.01 and not significant, respectively. Means of each factor designated by the same letter are not significantly different at 5% level using Duncan's MRT.

Obtained results suggest the importance of panicles number/m² and filled grains number/panicle in determining the magnitude of increase or decrease in grain yield. The superiority of SK2034H cultivar in grain yield was due to its highest number of panicles/m² and greatest number of filled grains/panicle. Gautam (2004), Singh *et al.* (2004), Abou Khalifa (2005), Zayed *et al* (2006), Zayed *et al* (2007), Alam *et al* (2009) and Zayed *et al* (2010) indicated that hybrid rice surpassed inbred rice in grain yield, number of panicles and number of filled grains/panicle.

2. Effect of phosphorus rate:

Application of phosphorus fertilizer resulted in a significant increase in grain and straw yields as well as all yield attributes compared with control (without phosphorus) in both seasons. Increasing phosphorus rate from 0 up to 36 kg P₂O₅/ha gradually increased number of panicles/m², panicle length, panicle weight, number of filled grains/panicle, grain yield and harvest index in both seasons. The inverse was true in unfilled grains %. However, adding 54 kg P₂O₅/ha produced heavier 1000-grain weight and straw yield. There was no significant difference in number of panicles/m², 1000-grain weight and straw yield between the two higher rates of 36 or 54 kg P₂O₅/ha in both seasons.

Table 4: Number of filled grains/panicle, unfilled grains % and 1000-grain weight of some rice cultivars as affected by phosphorus and zinc rates and their interaction in 2007 and 2008 seasons

Factor	Filled grains (No./panicle)		Unfilled grains (%)		1000- grain weight (g)	
	2007	2008	2007	2008	2007	2008
Cultivar (C):						
Giza 177	107.6c	92.9c	6.17a	5.15a	24.29a	24.98a
Giza 178	128.4b	145.8a	4.78b	2.64c	18.81d	18.74c
Sakha104	123.4b	105.5b	5.15b	4.44b	23.41b	25.06a
SK2034H	136.5a	146.2a	5.11b	3.87b	22.58c	21.17b
F test	**	**	**	**	**	**
Kg P₂O₅/ha (P):						
0	119.8b	115.7c	7.55a	5.31a	21.83b	21.29 b
18	124.3a	119.7b	5.44b	4.28b	22.12b	22.43 b
36	126.7a	127.7a	3.89c	3.02c	22.14b	22.78ab
54	125.2a	127.4a	4.32c	3.49c	22.98a	23.44 a
F test	**	**	**	**	**	**
Kg Zn SO₄/ha (Z):						
0	115.3c	114.9c	6.51a	5.50a	21.46b	21.84 c
12	125.0b	123.0b	5.52b	3.95b	22.34a	22.34 a
24	127.9a	125.6ab	4.64c	3.62b	22.58a	22.85 a
36	127.6a	126.8a	4.48c	3.03c	22.69a	22.92 a
F test	**	*	**	**	**	**
Interaction:						
C X P	*	**	*	NS	**	**
C X Z	**	*	*	**	**	**
P X Z	**	*	*	**	*	*
P X Z X C	*	**	NS	**	NS	NS

*, ** and NS indicate P < 0.05, P < 0.01 and not significant, respectively. Means of each factor designated by the same letter are not significantly different at 5% level using Duncan's MRT.

The trend of most attributes is similar to those of dry matter accumulation, leaf area index and number of tillers/m² and similar discussion could be cited. Application of 36 kg P₂O₅/ha increased grain yield through the increase in number of panicles/m², panicle weight, the number of filled grains/panicle and 1000-grain weight. The results are in agreement with those reported by Biswas and Dravid (2001), Ibrahim (2001), Kumar and Singh (2001), Hood (2002), Bharat (2006), Alam et al(2009) and Zayed *et al* (2010).

3. Effect of zinc rate:

Zinc application had a positive effect on yield and all yield attributes, except unfilled grains % in both seasons. Plants received 36 kg ZnSO₄/ha produced the highest number of panicles/m², panicle length, panicle weight, number of filled grains/panicle, 1000-grain weight, grain yield, straw yield and harvest index, while control plants produced the lowest one. Application of 24 kg ZnSO₄/ha was statistically at par with 36 kg ZnSO₄/ha in number of panicles/m², number of filled grains/panicle and 1000-grain weight in both seasons.

Table 5: Grain yield, straw yield and harvest index of some rice cultivars as affected by phosphors and zinc rates and their interaction in 2007 and 2008 seasons

Factor	Grain yield (t/ha)		Straw yield (t/ha)		Harvest index	
	2007	2008	2007	2008	2007	2008
Cultivar (C):						
Giza 177	4.51d	5.03d	9.29d	9.57c	0.32c	0.34c
Giza 178	6.38b	6.82b	10.90b	10.89b	0.36b	0.38b
Sakha104	5.17c	5.60c	10.44c	10.70b	0.32c	0.34c
SK2034H	7.00a	7.66a	11.29a	11.26a	0.38a	0.40a
F test	**	**	**	**	**	**
Kg P₂O₅/ha (P):						
0	4.89d	5.28c	9.66c	9.97c	0.33b	0.35b
18	5.30c	5.86b	10.35b	10.43b	0.33c	0.36b
36	6.65a	7.02a	11.03a	11.03a	0.37a	0.39a
54	6.31b	6.94a	10.94a	10.99a	0.35b	0.38a
F test	**	**	**	*	**	**
Kg Zn SO₄/ha (Z):						
0	4.87c	5.33d	9.51d	9.81c	0.33c	0.35d
12	5.50b	5.98c	10.36c	10.45b	0.34b	0.36c
24	6.24a	6.65b	10.93b	10.99a	0.36a	0.37b
36	6.45a	7.15a	11.18a	11.17a	0.36 a	0.39a
F test	**	**	**	**	**	**
Interaction:						
C X P	**	**	**	**	**	**
C X Z	**	**	**	**	**	**
P X Z	*	**	**	**	**	**
P X Z X C	*	**	NS	NS	NS	NS

*, ** and NS indicate P < 0.05, P < 0.01 and not significant, respectively. Means of each factor designated by the same letter are not significantly different at 5% level using Duncan's MRT.

The effect of zinc application on yield attributes mainly due to that zinc application increased dry matter, leaf area index and number of tillers. Also, these results might be attributed to that zinc application increased the translocation of the carbohydrate and other nutrients to the grains, consequently higher harvest index were obtained. Biswas and Dravid (2001),

Hood (2002), Malavolta *et al* (2002), Bharat (2006), Tariq *et al* (2007) , Khan *et al* (2009) and Shehata *et al* (2009) came to the same conclusion.

4. Effect of interaction:

All the first order interactions had a significant effect on the most of yields and yield attributes. However, the second order interaction had a significant effect on number of panicles/m², number of filled grains/panicle, 1000-grain weight, grain yield in the two seasons. Grain yield/ha as influenced by the first and the second order interactions in the two seasons are presented in tables 6 and7.

Table 6: Grain yield (t/ha) as affected by the interactions among rice cultivars, phosphors and zinc rates in 2007 season

P ₂ O ₅ (kg/ha)	ZnSO ₄ (Kg/ha)	Rice cultivars				Mean
		Giza177	Giza178	Sakha104	Sk2034H	
Cultivar x phosphorus						
0		4.06 h	5.15 f	4.21 gh	5.80 e	
18		4.38 gh	6.13 de	4.47 gh	6.24 d	
36		5.09 f	6.98 c	6.82 c	7.45 b	
54		4.53 g	6.98 c	5.20 f	8.52 a	
Cultivar x zinc						
	0	3.79 j	5.33 fg	4.41 i	5.95 e	
	12	4.38 i	5.91e	4.98 gh	6.72 d	
	24	4.76 h	6.99 cd	5.66 ef	7.57 ab	
	36	5.13 g	7.28 bc	5.64 ef	7.766 a	
Cultivar x phosphorus x zinc						P x zinc
0	0	3.39 k	4.40 g-k	3.90 ijk	4.90 f-k	4.17 h
	12	4.07 i-k	4.80 f-k	4.24 h-k	5.56 c-k	4.67 g
	24	4.23 h-k	5.49 c-k	4.24 h-k	6.35 b-k	5.08 f
	36	4.54 g-k	5.86 c-k	4.46 g-k	6.34 b-k	5.30 f
18	0	3.70 jk	5.23 d-k	3.99 ijk	5.33 c-k	4.56 g
	12	4.12 ijk	5.83 c-k	4.37 h-k	6.00 b-k	5.08 f
	24	4.70 g-k	6.52 b-j	4.71 g-k	6.72 a-j	5.66 de
	36	4.98 f-k	6.95 a-i	4.80 f-k	6.90 a-i	5.91 cd
36	0	4.03 ijk	6.13 b-k	5.20 d-k	6.26 b-k	5.41 ef
	12	4.84 f-k	6.50 b-j	6.52 b-j	6.95 a-i	6.20 c
	24	5.53 C-k	8.15 a-d	7.49 a-g	8.28 abc	7.36 a
	36	5.94 b-k	8.20 a-d	8.06 a-e	8.32 abc	7.63 a
54	0	4.03 ijk	5.49 c-k	4.54 g-k	7.29 a-h	5.34 ef
	12	4.48 g-k	6.52 b-j	4.80 f-k	8.38 abc	6.04 c
	24	4.58 g-k	7.80 a-f	6.22 b-k	8.92 ab	6.88 b
	36	5.04 e-k	8.12 a-d	5.23 d-k	9.48 a	6.97 b

Means of each factor designated by the same letter are not significantly different at 5% level using Duncan's MRT.

Cultivar × phosphorus rate interaction (CxP): The grain yield of Giza 177 and sakha 104 was increased by increasing phosphorus rate from 0 to 36 kg P₂O₅/ha and then it decreased in the two seasons. However, increasing phosphorus rate from 0 to 54 kg P₂O₅/ha increased grain yield of SK2034H and Giza 178 cultivars in both seasons. There was no significant difference between 36 and 54 kg P₂O₅/ha in grain yield of Giza 178 cultivar in both seasons. The highest grain yield was obtained from SK2034H cultivar when it received 54 kg P₂O₅/ha, while the lowest one were obtained from Giza 177 rice cultivar without phosphorus fertilizer in both seasons.

Table 7: Grain yield (t/ha) as affected by the interactions among rice cultivars, phosphors and zinc rates in 2008 season

P ₂ O ₅ (kg/ha)	ZnSO ₄ (kg/ha)	Rice cultivars				
		Giza177	Giza178	Sakha104	Sk2034H	Mean
Cultivar x phosphorus						
0		4.50 i	5.63 g	4.71 hi	6.29 f	
18		5.01 hi	6.63 ef	4.92 hi	6.89 de	
36		5.56 g	7.28 cd	7.08 de	8.15 b	
54		5.06 h	7.75 bc	5.67 g	9.30 a	
Cultivar x zinc						
	0	4.22 j	5.80 fgh	4.86 i	6.45 d	
	12	4.85 i	6.40 de	5.45 gh	7.20 c	
	24	5.30 hi	7.14 c	5.92 efg	8.23 b	
	36	5.76 fgh	7.94 b	6.17 def	8.75 a	
Cultivar x phosphorus x zinc						P x zinc
0	0	3.81u	4.9 m-u	4.3 st	5.4 k-u	4.62 i
	12	4.52 p-u	5.26 k-u	4.69 n-u	6.05 i-u	5.13 h
	24	4.68 n-u	5.97 i-u	4.69 n-u	6.86 e-o	5.55 g
	36	5.00 l-u	6.36 h-t	5.13 l-u	6.85 e-o	5.83 fg
18	0	4.14 tu	5.70 j-u	4.43 r-u	5.81 i-u	5.02 h
	12	4.65 o-u	6.32 i-t	4.82 m-u	6.50 g-s	5.57g
	24	5.16 l-u	7.02 e-m	5.18 l-u	7.24 d-l	6.15 ef
	36	6.08 i-u	7.46 c-k	5.26 k-u	8.04 b-i	6.7 1 d
36	0	4.47 q-u	6.63 f-r	5.66 j-u	6.76 e-p	5.88 fg
	12	5.31 k-u	6.99 e-m	7.02 e-m	7.46 c-k	6.70 d
	24	6.01 i-u	6.94 e-n	7.08 e-m	8.87a-e	7.22 c
	36	6.43 g-s	8.56 a-h	8.56 a-h	9.50 abc	8.26 a
54	0	4.47 q-u	5.97 i-u	5.00 l-u	7.82 b-j	5.81 fg
	12	4.92 m-u	7.02 e-m	5.26 k-u	8.81 a-f	6.50 de
	24	5.35 k-u	8.62 a-g	6.72 e-q	9.94 ab	7.66 b
	36	5.51k-u	9.37 a-d	5.70 j-u	10.6 a	7.80 b

Means of each factor designated by the same letter are not significantly different at 5% level using Duncan's MRT.

Cultivar × zinc rate interaction (CxZ): The highest grain yield was produced from SK2034H under 36 kg ZnSO₄/ha, while the lowest one was produced from Giza 177 without zinc fertilizer.

Phosphorus rate × zinc rate interaction (PxZ): The highest grain yield was produced from application of 36 kg P₂O₅/ha and 36 kg ZnSO₄/ha, while the lowest ones were obtained from control treatment (without phosphorus and zinc application).

Cultivar × Phosphorus rate × zinc rate interaction (CxPxZ): The highest grain yield was produced from SK2034H fertilized by 54 kg P₂O₅ and 36 kg ZnSO₄/ha, while the lowest ones were obtained from Giza177 without phosphorus and zinc application in the two seasons.

C. Chemical Composition:

Means of P, N and protein content in grains of some rice cultivars as affected by phosphors and zinc rates and their interaction are presented in Table 8.

1. Rice cultivars performance:

Rice cultivars exhibited significant differences in P, N and protein content in grains in both seasons. The hybrid rice cultivar SK2034H was

significantly superior to the other cultivars in all mentioned traits in both seasons.

Table 8: Phosphorus, nitrogen and protein content in grains of some rice cultivars as affected by phosphorus and zinc rates and their interaction in 2007 and 2008 seasons

Factor	Phosphorus content		Nitrogen content		Protein content	
	2007	2008	2007	2008	2007	2008
Cultivar (C):						
Giza 177	0.179c	0.171c	1.101c	1.165c	6.158c	6.513c
Giza 178	0.192b	0.184b	1.265b	1.305b	7.071b	7.296b
Sakha104	0.176c	0.167c	1.265b	1.314b	7.075b	7.341b
SK2034H	0.213a	0.224a	1.322a	1.383a	7.387a	7.729a
F test	**	**	**	**	**	**
Kg P₂O₅/ha (P):						
0	0.164d	0.157d	1.130d	1.179d	6.317d	6.586d
18	0.181c	0.176c	1.219c	1.271c	6.809c	7.108c
36	0.198b	0.200b	1.276b	1.324b	7.133b	7.399b
54	0.216a	0.214a	1.329a	1.393a	7.432a	7.785a
F test	**	**	**	**	**	**
Kg Zn SO₄/ha (Z):						
0	0.203a	0.211a	1.051c	1.106d	5.877c	6.179d
12	0.198b	0.198b	1.211b	1.257c	6.769b	7.029c
24	0.185c	0.188c	1.332a	1.378b	7.447a	7.703b
36	0.173d	0.166d	1.359a	1.425a	7.598a	7.968a
F test	**	**	**	**	**	**
Interaction:						
C X P	**	NS	NS	*	NS	*
C X Z	**	NS	NS	NS	NS	NS
P X Z	NS	**	*	NS	*	NS
P X Z X C	NS	NS	NS	NS	NS	NS

*, ** and NS indicate $P < 0.05$, $P < 0.01$ and not significant, respectively. Means of each factor designated by the same letter are not significantly different at 5% level using Duncan's MRT.

Giza178 and Sakha104 cultivars, being insignificant, followed SK2034H and surpassed Giza177 in grain nitrogen and protein content in both seasons. The lowest values of phosphorus content were produced from Sakha104 without significant difference with Giza177 cultivar in the two seasons. However, The lowest values of nitrogen and protein content were obtained from grains of the cultivar Giza177 in the two seasons. The superiority of the hybrid rice cultivar SK2034H in this trait might be due to its large ability for increasing nutrient uptake and its great heterosis and salt tolerance and in turn increased phosphorus and nitrogen content in grains. Previous researchers found varietal differences in P-content (Tomar *et al*, 1994 and Zayed *et al*, 2010), N-content (El-kady and Abd EL-Wahab 1999) and protein content (Ram *et al*, 1997 and Zayed *et al*, 2007).

2. Effect of phosphorus rate:

Phosphorus, nitrogen and protein contents in rice grains were gradually increased by each increment of phosphorus fertilizer in the two seasons. This is mainly due to the increase in soluble phosphates under higher rate of phosphorus application, which increased phosphorus and nitrogen uptake and in turn grain P and N content and consequently protein.

In this connection, Prakash and Badrinath (1995), Brohi *et al* (1998), Masthan *et al* (1998) and Zayed *et al* (2010) found that N and P-content of rice grain were increased by increasing phosphorus rate. Zayed *et al* (2010) added that increasing phosphorus rate increased crude protein content in rice grains under saline soil.

3. Effect of zinc rate:

Zinc application had an opposite effect on phosphorus content of rice grains in the two seasons. Phosphorus content of grains was gradually decreased by increasing zinc rate from 0 to 36 kg ZnSO₄/ha. This is mainly due to the antagonistic effect between phosphorus and zinc. Tomar *et al* (1994) and Taban (1995) came to the same conclusion. However, Zinc application resulted in a considerably increase in nitrogen and protein content of rice grains compared with control treatment (without zinc fertilizer) in the two seasons. Application of zinc at the rate of 36 kg ZnSO₄/ha produced the highest nitrogen and protein content of grains in the two seasons. The rates of 24 and 36 kg ZnSO₄/ha did not differ in this respects in the first season. The favorable effect of zinc fertilization on these traits was viewed by Chen and Fan (1997) and Ranjha *et al* (2001).

4. Effect of interaction:

The interactions of cultivar × phosphorus rate for phosphorus content in rice grains in the first season, nitrogen and protein content in the second season; cultivar × zinc rate for phosphorus content in rice grains in the first season and phosphorus rate × zinc rate for phosphorus content in grains in the second season, nitrogen and protein content in the first season were significant.

It can be concluded that sowing SK2034H rice cultivar and application phosphorus fertilizer at the rate of 54 kg P₂O₅/ha and Zinc fertilizer at the rate of 24 or 36 kg ZnSO₄ could be recommended to produce optimum grain yield per unit area under saline soil condition.

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تأثير التسميد بالزنك والفسفور على محصول الأرز تحت ظروف الاراضى الملحية
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أجريت تجربتان حقليتان بالمزرعة البحثية بمحطة البحوث الزراعية بالسرو بمحافظة دمياط خلال موسمي الزراعة ٢٠٠٧ و ٢٠٠٨، لدراسة تأثير إضافة الفسفور (صفر، ١٨، ٣٦ و ٥٤ كجم فوسفور/هكتار) والزنك (صفر، ١٢، ٢٤ و ٣٦ كجم كبريتات زنك/هكتار) على بعض أصناف الأرز (جيزة ١٧٧، جيزة ١٧٨، سخا ١٠٤، هجين SK2034H) تحت ظروف الاراضى الملحية، وتتلخص النتائج المتحصل عليها فيما يلى:

تفوقت نباتات صنف الأرز الهجين SK2034H على نباتات الأصناف الأخرى فى دليل مساحة الورقة، المادة الجافة المتجمعة، طول النبات، عدد الأشطاء/جورة، عدد السنابل/جورة، طول السنبله، وزن السنبله، عدد الحبوب الممتلئه/سنبله، محصول الحبوب، محصول القش، دليل الحصاد، ومحتوى الحبوب من الفسفور، النيتروجين و البروتين الخام فى كلا الموسمين. بينما أعطى الصنف جيزه ١٧٧ أثقل وزن الف حبه، وأعطى الصنف جيزه ١٧٨ أقل نسبة حبوب فارغة.

أدى استخدام السماد الفوسفاتى الى زيادة معنوية فى معظم صفات النمو والمحصول ومكوناته، نسبة الفسفور والنيتروجين والبروتين فى الحبوب وإنخفاض فى نسبة الحبوب الفارغة عن معاملة المقارنة (بدون سماد فوسفاتى). ادت زيادة معدل الفسفور من صفر الى ٣٦ كجم فوسفور/هكتار الى زيادة معنوية فى دليل مساحة الورقة، عدد الأشطاء/جورة، عدد السنابل/جورة، وزن السنبله، طول السنابل، عدد الحبوب الممتلئه/سنبله، محصول الحبوب، ودليل الحصاد فى كلا الموسمين. وقد تم الحصول على أعلى القيم فى وزن

الألف حبه ، محصول القش، محتوى الحبوب من الفسفور و النيتروجين و البروتين الخام من التسميد الفوسفورى بمعدل ٥٤ كجم فو٢ أه/هكتار. ولم يتأثر ارتفاع النبات معنويا باضافة الفسفور . أدت زيادة معدل الزنك من صفر إلى ٣٦ كجم كبريتات زنك /هكتار الى زيادة معنويه فى دليل مساحة الورقة ، المادة الجافه المتجمعة ، عدد الاشطاء/جورة ، طول السنبله، وزن السنبله، وزن الألف حبه، محصول الحبوب، محصول القش، دليل الحصاد، نسبة النيتروجين والبروتين الخام في الحبوب فى كلا الموسمين. والعكس صحيح فى نسبة الحبوب الفارغه، نسبة الفسفور في الحبوب. وقد أدى إستخدام ٢٤ كجم كبريتات زنك /هكتار الى الحصول على أعلى القيم فى عدد الاشطاء/جورة ، عدد السنابل/جورة ، عدد الحبوب الممتلئه/ سنبله بدون فرق معنوى عن إستخدام ٣٦ كجم كبريتات زنك /هكتار. ولم يتأثر ارتفاع النبات معنويا باضافة الزنك.

أثرت جميع التفاعلات بين عوامل الدراسة معنويا على محصول الحبوب فى الموسمين. وقد تم الحصول على أعلى محصول حبوب بإستخدام الصنف الهجين SK2034H المسمد بمعدل ٥٤ كجم فو٢ أه + ٣٦ كجم كبريتات الزنك للهكتار. ولم يختلف محصول هذا الصنف معنويا بالتسميد بمعدل ٣٦ كجم فو٢ أه + ٢٤ كجم كبريتات الزنك للهكتار عن المعدل السابق ذكرة.

وعامة يمكن ان نستخلص من النتائج المتحصل عليها من هذه الدراسة أن زراعة صنف الارز هجين SK2034H و اضافة السماد الفوسفاتى بمعدل ٥٤ كجم فو٢ أه/هكتار و الزنك بمعدل ٢٤ أو ٣٦ كجم كبريتات الزنك/هكتار يمكن ان ينصح به لانتاج اعلى محصول من الحبوب من وحدة المساحة تحت ظروف الاراضى الملحية.

قام بتحكيم البحث

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