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Original Research Article

Impact of different rates of phosphoric acid foliar spraying on rice growth and yield traits under normal and saline soils conditions

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Abstract: The present study was carried out in Egypt, at farm of Sakha Agricultural Research Station in Kafr El-Sheikh Governorate as a normal soil, and El-Sirw Agricultural Research station in Dommitta Governorate as a saline soil during 2017 and 2018 seasons. The main objective of this investigation was to find out the response of Giza 178 rice cultivar to different rates of phosphoric acid spraying in comparison to the basal *application* of calcium super-phosphate as a standard treatment under two types of soil; normal and saline soils. The experiments were performed in a randomized complete block design with four replicates for each soil. The treatments are including foliar spraying of phosphoric acid at the rates of 3, 6 and 9 liters ha^{-1} applied into three times at mid tillering, panicle initiation and mid booting stages. Basal application of the recommended dose of phosphorous in a form of calcium super phosphate (15.5 % P_2O_5) at the rate of 37.5 kg ha^{-1} as a standard treatment, and control treatment (no phosphorus application). The obtained results could be summarized as follows; the tested phosphorous treatments significantly influenced the studied growth characters, phosphors uptake kg P, leaf phosphorus content, grain yield and its attributes under both soils, in the two seasons of study. The recommended dose of calcium super phosphate as a standard basal application recorded the highest values of the most studied characters under both, normal and saline soils during the two seasons, with insignificant differences with the rate of 9 liters $ha^{-1}$of phosphoric acid spraying thrice. On the other hand, the control treatment showed the lowest values of these studied characters under both soils, in the two seasons. It could be recapitulated that, spraying phosphoric acid at the rate of 9 liters H_3PO_4 ha^{-1} could be equivalent to the recommended dose of calcium super- phosphate under normal and saline soils**.**
Keywords: Rice, Phosphorus, Phosphoric acid, Calcium super phosphate, Salinity.

INTRODUCTION

Rice is the main food of more than half of world's people (FAOSTAT 2016). It is the source of dietary energy for the people of many countries especially in Asia. Efficient nutrient management in rice considered one of the important factors that control production levels of rice (Singh and Singh 2017). Phosphorus is one of the essential elements required for rice growth and development; it ranked the second in importance after nitrogen. It acts vital roles in the plants such as; early root and seedling growth, promotion of early heading and uniform maturity, seed formation and quality. Also, it plays a physiological role in photosynthesis, energy storage and transfer, respiration and cell division (El-Ghamry *et al.* 2009). In Egypt, the phosphorus availability in soil solution is relatively low, because they are mainly fixed on the soil complex as insoluble forms (Alshaal and El-Ramady 2017). Moreover, farmers used to add the entire amount of phosphorus during soil tillage. As a result, a high percent of the added phosphorus fixed in an insoluble phase unavailable for plant uptake. Therefore, phosphorus management must focus on the buildup and maintenance of adequate available phosphorus level in the soil to ensure that it does not limit rice growth (Fairhurst *et al.* 2007). Nutrients foliar application is a bypass approach that could be used to replace soil-applied fertilizer, whenever it does not perform well enough. It overcomes soil fertilization limitations such as; leaching, insoluble fertilizer precipitation, antagonism between certain nutrients, heterogenic soils unsuitable for low rates and fixation/absorption reactions like in the case of phosphorus and potassium (Alshaal and El-Ramady 2017). Phosphoric acid, also

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called orthophosphoric acid, (H_3PO_4), the most important oxygen acid of phosphorus, used to make phosphate salts for fertilizers. Many researchers demonstrated the effect of phosphoric acid foliar application on plants, Mohamed and Maha (2016), showed that, application of phosphoric acid reflected the highest values of plant growth, chemical constituent, head yield and its quality compared with calcium super phosphate and rock phosphate. Mosali *et al.* (2006) found that, foliar application of phosphoric acid was effective in compensating mid-season phosphorus deficiency in winter wheat by low rates of foliar applied and subsequently resulted in higher phosphorus use efficiency. Taking into consideration that, one-fourth to one-third of the rice cultivated area in Egypt located in areas affected by various degrees of salinity as mentioned before. Generally, phosphorus application in different methods and sources had apparent variation with high affinity to increase rice yield and other crops, Choudhury et al.(2007), Elayaraja and Angayarkanni(2007),Ehsan et al.(2009) and Alinajati and Mirshekari (2011). The aim of the present research was to study and find out the response of rice plants (Giza 178 cv.) to different rates of phosphoric acid spraying in comparison to the basal application of calcium super-phosphate as a standard treatment under normal and saline soil conditions.

MATERIALS AND METHODS

The field experiments were conducted at Agricultural Research farms of Sakha (normal soil) in Kafr El-Sheikh Governorate and El-Sirw (Saline soil) in Dommitta Governorate, Egypt during 2017 and 2018 seasons. The experiments were designed to study the effect of different rates of phosphoric acid spraying in comparison to the basal application of calcium super-phosphate as a standard treatment on the growth and productivity of Giza 178 rice cv. under normal and saline soil conditions. Three rates of phosphoric acid were sprayed: 3, 6, and 9 liters ha^{-1} applied three times, at mid tillering, panicle initiation and mid booting stages. However, applications of the recommended dose of phosphorous at the rate of 37.5kg ha^{-1} in the form of calcium super- phosphate (15.5% P_2O_5) were basal applied as a standard treatment. Phosphoric acid was dissolved in 300 liter water ha^{-1} for each treatment at each time. Worthy to mention that, basal application of calcium super phosphate means broadcasting the fertilizer before tillage to uniformly distribute the fertilizer over the entire field and to mix it with soil. Randomized complete block design with four replicates was used under both soils. The chemical and physical properties of soils in both experimental sites were analyzed and arranged in Table 1.

In both seasons, seed' sowing was conducted on 25 April. Then, at the age of 30 days (on 25 May) seedlings were transplanted at spacing of 20 x 20 cm with 4 seedlings $hill^{-1}$ as apart in each site. The plot size was 2m wide x 5m length (10 m^2). Phosphorous was applied as indicated before in the treatments. Nitrogen in the form of urea (46% N) at the rate of 165 kg N ha^{-1} was applied in three equal doses in the saline soil, and in two equal doses in the normal soil. Potassium in the form of potassium sulfate (48% K_2o) at the rate of 57 kg k_2O ha^{-1} was applied as a basal application.

At heading, five hills were randomly taken from each plot, transferred to lab to estimate dry matter production (DM $hill^{-1}$), leaf area index (LAI) and chlorophyll content as well as phosphorous uptake and leaf phosphors content (P %) according to Yoshida *et al.* 1976.

Table-1. Some physical and chemical properties of both soils (normal and saline) before cultivation (0-30 cm) depth, in the two experimental sites in 2017 and 2018 seasons.

Properties	Normal soil (Sakha)		Saline soil (El- Sirw)	
Seasons	2017	2018	2017	2018
PH	7.9	8.1	8.4	8.3
ECe $dS.m^{-1}$	2.3	2.5	8.3	8.0
O.M. %	1.15	1.2	1.15	1.2
Available N, mg kg^{-1}	32	31	29	30
Available P, mg kg^{-1}	13	12	10	11
Available K, mg kg^{-1}	420	410	400	380
Soluble cations meq. L^{-1}	-	-	-	-
Ca^{++}	5.0	5.2	9.0	8.0
Mg^{++}	3.30	4.00	11.40	10.0
K^+	0.35	0.43	0.50	0.70
Na^+	15.0	16.00	63.0	69.0
Soluble anions meq.L^{-1}	-	-	-	-
CO3--	-	-	-	-
HCO3-	3.0	4.00	9.64	8.64
CL-	16.0	17.6	63.5	60.6
SO4--	4.00	5.43	10.33	11.33
Available micronutrients ppm	-	-	-	-
Fe^{++}	5.73	5.22	5.23	5.95
Zn^{++}	1.12	1.21	0.90	1.01
Mn^{++}	4.70	4.30	4.60	4.50
Soil texture	Clayey	Clayey	Clayey	Clayey

At harvest, panicles of ten guarded hills for each plot were counted to determine the number of panicles hill^{-1}and plant height (cm) was measured. Ten main panicles from each experimental plot were used to determine panicle length (cm), number of filled and unfilled grains panicle $^{-1}$, panicle and 1000-grains weight. The plants of the six inner rows of each experimental plot were harvested, dried, threshed, then grain and straw yields were determined at 14 % moisture content and converted into ton ha^{-1}. Rice grain yield and economic evaluation according to (Zayed *et al.* 2011).

All data collected were subjected to standard statistical analysis of variance following the method described by Gomez and Gomez (1984) using Michigan State University Computer Statistical Package (MSTAT-C). Different Means were compared using (Duncan, 1955), when the ANOVA showed significant differences ($P<0.05$) or highly significant differences ($P<0.01$).

RESULTS AND DISCUSSION

Data in Table 2 showed that, the effect of the used rates of phosphoric acid as a foliar spray and calcium super phosphate as a standard basal application on chlorophyll content and leaf area index (LAI) for Giza 178 rice cultivar under normal and saline soils in 2017 and 2018 seasons. It is obvious that, application of phosphorus otherwise foliar or basal application had a highly significant positive effect on chlorophyll content and leaf area index under both of soils in the two seasons except chlorophyll content in the first season under normal soil, was only significant. The highest values of chlorophyll content were obtained with the treatment of calcium super-phosphate as a standard basal application in 2017 and 2018 seasons without any significant differences with phosphoric acid spraying thrice at the rates of 9 and 6liters ha^{-1} under normal soil, and the rate of 9liters ha^{-1} under saline soil in the first season only. While, in the second one calcium super phosphate highly significant surpassed all rates of phosphoric acid in chlorophyll content trait. On the other hand, the lowest values of chlorophyll content were recorded by control treatment under both soils in the two seasons. It is noticeable that, chlorophyll content gradually responded to increment of phosphoric acid spraying rates up to 9 liters ha^{-1} under both soils conditions that might be due to deficiency of phosphorus availability. Also, the highest values of LAI were recorded by the basal application of calcium super phosphate without any significant differences with phosphoric acid spraying at the rate of 9 liters ha^{-1}, whereas the lowest values were obtained with control treatments, under normal and saline soils in both seasons. The positive role of phosphorus application on both chlorophyll content and LAI is mainly due to its role as a part of the chemical structures of adenosine di and tri-phosphate (ADP and ATP), which is the source of energy that drives the biochemical reactions within the plant; such as plant pigments formation leading to high chlorophyll content. These results are in accordance with those obtained by, Rotaru *et al.* (2015) when they reported that, Supplementation of phosphorus on soybean at the highest (recommended) rate resulted in greater values of total chlorophyll and chlorophyll a content compared to unfertilized plants (control), however no significant changes of chlorophyll b were recorded under a sufficient water soil regime.

Table 2. Chlorophyll content (SPAD value) and leaf area index (LAI) for Giza 178 rice cultivar' plants as affected by the studied phosphorus treatments, under normal and saline soils in 2017 and 2018 seasons.

Characters	Chlorophyll content				LAI			
Season	2017		2018		2017		2018	
Soil	Normal	Saline	Normal	Saline	Normal	Saline	Normal	Saline
Control	39.15^{c}	37.07^{d}	39.63^{e}	37.70^{e}	4.46^{d}	3.13^{d}	4.43^{d}	3.43^{d}
3 liters H_3PO_4 ha^{-1}	40.40^{b}	38.07^{c}	40.17^{d}	38.30^{d}	5.10^{c}	3.81^{c}	5.20^{c}	4.07^{c}
6 liters H_3PO_4 ha^{-1}	42.00^{a}	40.40^{b}	41.30^{c}	39.60^{c}	5.45^{b}	4.37^{b}	5.64^{b}	4.37^{b}
9 liters H_3PO_4 ha^{-1}	42.30^{a}	41.00^{a}	41.83^{b}	40.33^{b}	5.97^{ab}	4.75^{ab}	5.99^{a}	4.77^{a}
basal37.5kg P_2O_5 ha^{-1}	42.15^{a}	41.33^{a}	42.50^{a}	41.37^{a}	6.20^{a}	5.03^{a}	6.13^{a}	4.97^{a}
F-Test	*	**	**	**	**	**	**	**

Means designated by the same letter in the same column are not significantly different a according to Duncan's Multiple Range Test.

*, ** and N.S. indicate $P < 0.05$, $P < 0.01$ and not significant, respectively.

Lin *et al.* (2009) found that, leaf chlorophyll, carotenoides and total soluble protein contents decreased with severe decrease in leaf P resulted by low P supply. Also, cell division and elongation are considered other biochemical reactions that demands adenosine di and tri-phosphate as energy compounds; and consequently activated more with raising phosphorus rate, finally reflected in larger leaf area (LAI). Chen *et al.* (2013) mentioned that, phosphorus fertilization increased the leaf area index LAI, leaf area duration (*LAD*), stem and leaf dry matter accumulation (DMA) of maize significantly. Moreover, Fernández *et al.* (2014) studied the effect of phosphorus (P) nutritional status on wheat leaf surface properties, in relation to foliar P absorption and translocation, and they found that phosphorus foliar application (2% ammonium phosphate ($NH_4H_2PO_4$)) increased wheat dry weight, tissue P concentrations and leaf area. Other similar findings were obtained by (Zayed *et al.* 2010, 2011 and 2016).

Table 3. Dry matter hill^{-1} (g) and leaf phosphorus content (P %) for Giza 178 rice cultivar' plants as affected by the studied phosphorus treatments, under normal and saline soils, in 2017 and 2018 seasons.

Characters	Dry matter production hill^{-1} (g)				Leaf phosphorus content (P %)			
Season	2017		2018		2017		2018	
Soil	Normal	Saline	Normal	Saline	Normal	Saline	Normal	Saline
Control	41.48^{c}	28.83^{c}	44.00^{d}	30.67^{d}	0.217^{d}	0.193^{e}	0.24^{d}	0.21^{e}
3 liters H_3PO_4 ha^{-1}	45.08^{bc}	36.13^{b}	48.67^{c}	37.00^{c}	0.263^{c}	0.223^{d}	0.27^{c}	0.24^{d}
6 liters H_3PO_4 ha^{-1}	48.49^{b}	37.73^{b}	56.00^{b}	42.00^{b}	0.293^{bc}	0.244^{c}	0.31^{b}	0.276^{c}
9 liters H_3PO_4 ha^{-1}	57.97^{a}	41.27^{a}	65.00^{a}	44.53^{a}	0.313^{b}	0.270^{b}	0.317^{b}	0.30^{b}
basal 37.5 kg P_2O_5 ha^{-1}	59.33^{a}	43.33^{a}	66.07^{a}	46.33^{a}	0.350^{a}	0.320^{a}	0.363^{a}	0.317^{a}
F-Test	**	**	**	**	**	**	**	**

Means designated by the same letter in the same column are not significantly different a according to Duncan's Multiple Range Test.
*, ** and N.S. indicate $P < 0.05$, $P < 0.01$ and not significant, respectively.

Data in Table 3 showed the effect of the studied phosphorus treatments on dry matter production hill^{-1} and leaf phosphors content (P%) under normal and saline soils in 2017 and 2018 seasons. In both seasons and under the two soil types. The treatment of calcium super-phosphate as a standard basal application ranked the first, and recorded the highest values of dry matter production and leaf phosphors content (P%), with insignificant differences with phosphoric acid spraying at the rate of 9 liters ha^{-1} only for dry matter production trait. While, it surpassed all rates of phosphoric acid spraying for leaf phosphors content (P%) trait. However, the lowest means of dry matter production and leaf phosphors content (P%) were recorded by control treatments. It is clear from data that, irrespective the superiority of the standard basal application of calcium super-phosphate, there was a gradual increment in dry matter production and leaf phosphors content (P%) with increasing the rate of phosphoric acid spraying from 3 to 9 liters ha^{-1} which reach to be at a par with a standard basal application regarding dry matter production only without reaching that superiority level regarding leaf phosphors content (P%) in both seasons and under the two soil types.

Notably, Phosphorus has a significant effect to reduce the adverse effects of salinity on growth. As phosphorus increased, it ameliorated the adverse effect of salinity on shoot length and dry weight of different parts of plants. Furthermore, the enhancing effect of phosphoric acid on vegetative growth may be due to its acidity role in reducing soil pH, which can improve the availability of other mineral elements to be more soluble and available for absorption by plants, and in turn increasing the vegetative growth (Zayed *et al.* 2016). The current findings are in agreement with those obtained by Wu, *et al.* (2004), who reported that, the phosphorus content in all parts of seedlings were reduced under phosphorus stress, when they studied the response of the chlorophyll biosynthesis, photosynthesis and biomass partitioning of *Fraxinus mandchurica* seedlings to phosphorus stress. Moreover, (Naheed *et al.* 2008) found that, phosphorous application whether basal or foliar spraying application encouraged rice growth involving shoots and roots systems, resulted in a high capability for nutrient uptake. Also, foliar spray of phosphorus increased significantly its content in leaves, and thus contributes in avoiding the problem occurs under saline soils (precipitation of phosphate ions with calcium ions problem). Lin *et al.* (2009), noted that, root and shoot dry weight and leaf P content increased as P supply increased, and vise versa. In addition, Leaf Chlorophyll, Carotenoides and total soluble protein contents decreased with severe decrease in leaf P content which supports the previous mention findings concerning chlorophyll content. Also, Sima *et al.* (2012) recapitulated that, higher amounts of phosphorus minimized the destructive effects of soil salinity by increasing the fresh weight of roots and K^+ absorption under salt stress conditions, and also increased fresh, dry weights of shoots and the amounts of P absorbed by barley plants.

Concerning to the effect of the studied phosphorus treatments on phosphorus uptake kg P ha^{-1} and number of tillers hill^{-1}, data in Table 4 showed that, a highly significant effect for the studied phosphorus treatments had been noticed under normal and saline soils in the two seasons. Both of calcium super-phosphate as a standard basal application and phosphoric acid spraying rates highly significant increased phosphorus uptake kg P ha^{-1} and number of tillers hill^{-1} compared to control treatment.

In both seasons and under the two soil' types, basal application of 37 kg P_2O_5 ha^{-1} scored the highest values of phosphors uptake kg P ha^{-1} and number of tillers hill^{-1}. Spraying phosphoric acid at the rate of 9liters ha^{-1} ranked the second grade after the basal application with insignificant differences with 6 liters ha^{-1} only for number of tillers hill^{-1}, while the rate of 6 liters ha^{-1} ranked the third for phosphors uptake kg P ha^{-1}, followed by the rate of 3 liters ha^{-1}. On contrast, the control treatment ranked the last and recorded the lowest values for these traits.

Phosphorous application either as a basal or spray significantly increased the nutrient content that may be due to its roles in fixing atmospheric nitrogen, reducing soil pH and increasing solubility of phosphorus and potassium in root rhizosphere and consequently increased nutrient uptake and accumulation by plants (Alam *et al.* 2009a). In addition, Abdolzadeh *et al.* (2010) reported that, the rate of P uptake increased at higher P concentrations. However, in a hydroponic culture system, where P supply is not limited by diffusion or solubility, the higher p concentrations caused toxicity with visible symptoms such as leaf desiccation and drying of plants. Also, Wu *et al.* (2011) attributed the high phosphorus uptake to higher phosphorus content in soil solution under high rates of phosphorus application. Furthermore, Rashwan *et al.* (2019), found that application of the phosphorus recommended dose caused a significant increase in phosphorus uptake, and attributed it to the high plant root volume that ameliorated the P absorption by exploiting more of soil leading to improve physiological reactions in plants such as photosynthetic and vegetative growth.

Concerning to number of tillers hill^{-1}; results of our study support that phosphorus is a tillering stimulator in cereals, the significant positive impact of phosphorus is an expected result to its role in encouraging some of biochemical reactions such as, cell division and elongation, dry matter accumulation resulted in more shoots and roots. Imrul *et al.* (2016), found that, the highest numbers of effective, ineffective and total tillers hill^{-1} were recorded under the highest rate of applied phosphorus. Also, Alinajoati sisie and Mirshekari (2011) noted that, phosphorous application activates tillers development, roots and shoots growth. Moreover, Mumtaz *et al.* (2014), found an increase in number of tillers with increasing phosphorus application under optimum irrigation conditions at critical growth stages of wheat.

Table 4. Phosphorus uptake kg P ha^{-1} and number of tillers hill^{-1} for Giza 178 rice cultivar' plants as affected by the studied phosphorus treatments, under normal and saline soils in 2017 and 2018 seasons.

Characters	P uptake kg P ha^{-1}				Number of tillers hill^{-1}			
Season	2017		2018		2017		2018	
Soil	Normal	Saline	Normal	Saline	Normal	Saline	Normal	Saline
Control	22.50^e	11.50^e	26.40^d	17.68^e	16.50^d	13.00^d	17.88^d	13.58^d
3 liters H_3PO_4 ha^{-1}	29.64^d	20.14^d	32.85^c	22.80^d	18.20^c	15.55^c	18.70^c	16.00^c
6 liters H_3PO_4 ha^{-1}	35.51^c	23.02^c	43.40^b	27.67^c	19.30^b	17.60^b	19.88^b	18.60^b
9 liters H_3PO_4 ha^{-1}	42.06^b	27.86^b	45.17^b	32.65^b	19.80^b	17.75^b	19.90^b	18.35^b
basal 37.5 kg P_2O_5 ha^{-1}	51.91^a	34.66^a	59.96^a	36.72^a	21.50^a	18.90^a	22.20^a	19.10^a
F-Test	**	**	**	**	**	**	**	**

Means designated by the same letter in the same column are not significantly different a according to Duncan's Multiple Range Test.
*, ** and N.S. indicate P < 0.05, P < 0.01 and not significant, respectively.

The mean values in Table 5 indicate that, panicle number hill^{-1} and plant height (cm) highly significant influenced by the studied phosphorus treatments under normal and saline soils during 2017 and 2018 seasons. Phosphorus application highly significant increased panicle number hill^{-1} compared to control. The highest values of panicle number were obtained by applied 37.5 kg P_2O_5 ha^{-1} as a standard basal application under normal and saline soils in both seasons, with insignificant difference with the rate of 9 liters ha^{-1} under saline soil in the first season only. Furthermore, the tallest plant height was obtained by adding 37.5 kg P_2O_5 ha^{-1} as a standard basal application without significant differences with spraying phosphoric acid at the rates of 9 and 6 liters ha^{-1} under normal and saline soils in both seasons.

Table 5. Number of panicles hill^{-1} and plant height (cm) for Giza 178 rice cultivar' plants as affected by the studied phosphorus treatments, under normal and saline soils in 2017 and 2018 seasons.

Characters	Panicle number hill^{-1}				Plant height (cm)			
Season	2017		2018		2017		2018	
Soil	Normal	Saline	Normal	Saline	Normal	Saline	Normal	Saline
Control	15.43^c	11.47^c	15.13^e	15.43^c	86.6^c	81.8^b	85.30^c	76.87^c
3 liters H_3PO_4 ha^{-1}	16.37^b	13.40^b	15.83^d	16.60^b	87.3^b	83.1^{ab}	87.67^b	80.60^b
6 liters H_3PO_4 ha^{-1}	16.60^b	13.47^b	16.40^c	16.80^b	89.1^{ab}	84.4^{ab}	89.37^a	83.73^a
9 liters H_3PO_4 ha^{-1}	16.80^b	14.42^a	16.63^b	16.37^b	89.4^a	85.5^{ab}	89.43^a	84.50^a
basal 37.5 kg P_2O_5ha^{-1}	17.63^a	14.73^a	17.40^a	17.40^a	91.0^a	86.0^a	90.20^a	84.67^a
F-Test	**	**	**	**	**	**	**	**

Means designated by the same letter in the same column are not significantly different a according to Duncan's Multiple Range Test.
*, ** and N.S. indicate P < 0.05, P < 0.01 and not significant, respectively.

Generally, as mentioned before, Phosphorus is a tillering stimulator and enriches rice plants with ADP and ATP energy compounds that encourage cell division and elongation, dry matter accumulation.

Adequate phosphorus allows these important biochemical processes to be operated at optimum rates, resulted in taller and more tillering plants, that consequently increases number of panicles. In addition, its positive impact on flowering and bud formation. These results are in the same trend with Mumtaz *et al.* (2014), where they pointed out that, higher application rate of phosphorus resulted in taller plants, and Imrul *et al.* (2016), when they revealed that, with increasing the application of phosphorus, plant height showed ascending trend, but after a certain level plant height increased very slowly.

Table 6. Panicle length (cm) and panicle weight (g) for Giza 178 rice cultivar' plants as affected by the studied phosphorus treatments, under normal and saline soils in 2017 and 2018 seasons.

Characters	Panicle length (cm)				Panicle weight (g)			
Season	2017		2018		2017		2018	
Soil	Normal	Saline	Normal	Saline	Normal	Saline	Normal	Saline
Control	21.43^{c}	20.60^{d}	20.90^{d}	19.07^{d}	2.83^{b}	2.33^{c}	2.90^{d}	2.43^{d}
3 liters H_3PO_4 ha^{-1}	22.30^{b}	21.60^{c}	21.50^{c}	19.60^{c}	2.94^{b}	2.59^{d}	3.10^{c}	2.67^{c}
6 liters H_3PO_4 ha^{-1}	22.81^{a}	22.17^{b}	21.87^{b}	19.97^{b}	3.17^{b}	2.87^{b}	3.33^{b}	2.88^{b}
9 liters H_3PO_4 ha^{-1}	22.85^{a}	22.90^{a}	22.30^{a}	20.60^{a}	3.37^{ab}	2.94^{ab}	3.65^{a}	3.10^{a}
basal 37.5 kg P_2O_5 ha^{-1}	23.07^{a}	23.17^{a}	22.43^{a}	20.80^{a}	3.65^{a}	3.13^{a}	3.73^{a}	3.30^{a}
F-Test	**	**	**	**	*	**	**	**

Means designated by the same letter in the same column are not significantly different a according to Duncan's Multiple Range Test.
*, ** and N.S. indicate P < 0.05, P < 0.01 and not significant, respectively.

Data in Table 6 revealed that, panicle length and panicle weight were highly significant affected by the studied phosphorus treatments under normal and saline soils during 2017 and 2018 seasons. Application of the recommended dose of calcium super-phosphate as a standard basal application introduced the longest and heaviest panicles under normal and saline soils in both seasons with insignificant differences with those obtained by phosphoric acid spraying at the rate of 9 liters ha^{-1} under normal and saline soil in both seasons regarding panicle length and weight. However, the lowest values of panicle length and weight were produced by control treatment under the tested soils in both seasons. Also, a gradual increase could be noticed in these two traits with increasing the rate of phosphoric acid spraying from 3 up to 9 liters ha^{-1} under normal and saline soils in both seasons.

Table 7. Number of filled grains panicle^{-1} and unfilled grains panicle^{-1} for Giza 178 rice cultivar' plants as affected by the studied phosphorus treatments, under normal and saline soils in 2017 and 2018 seasons.

Characters	No. of filled grains panicle^{-1}				No. of unfilled grains panicle^{-1}			
Season	2017		2018		2017		2018	
Soil	Normal	Saline	Normal	Saline	Normal	Saline	Normal	Saline
Control	115.7^{d}	102.9^{d}	114.3^{d}	89.67^{d}	27.20^{a}	29.67^{a}	23.67^{a}	41.00^{a}
3 liters H_3PO_4 ha^{-1}	125.1^{c}	114.6^{c}	126.3^{c}	103.3^{c}	15.87^{b}	26.13^{b}	17.67^{b}	34.00^{b}
6 liters H_3PO_4 ha^{-1}	133.3^{b}	121.0^{b}	135.0^{b}	120.0^{b}	12.23^{c}	25.60^{b}	11.60^{c}	17.67^{c}
9 liters H_3PO_4 ha^{-1}	139.5^{a}	127.9^{a}	139.9^{a}	124.3^{a}	8.33^{d}	15.70^{c}	11.33^{c}	16.67^{c}
basal 37.5 kg P_2O_5 ha^{-1}	140.0^{a}	129.0^{a}	142.7^{a}	124.9^{a}	7.70^{d}	15.50^{c}	10.67^{c}	16.50^{c}
F-Test	**	**	**	**	**	**	**	**

Means designated by the same letter in the same column are not significantly different a according to Duncan's Multiple Range Test.
*, ** and N.S. indicate P < 0.05, P < 0.01 and not significant, respectively.

Data in Table 7 confirmed that, the tested phosphorus treatments had a highly significant impact on number of filled and unfilled grains panicle^{-1} under normal and saline soils. As expected, in both seasons and under normal and saline soils, control treatments recorded the minimum number of filled grains panicle^{-1}, whereas it recorded the maximum number of unfilled grains panicle^{-1} that might be due to deficiency of phosphorus supply to plants. On the other side, there were a gradual increment in number of filled grains and a gradual reduction in unfilled grains panicle^{-1} with increasing the rate of the applied phosphoric acid from 3 up to 9 liters ha^{-1}, Moreover, the highest rate of the applied phosphoric acid 9 liters ha^{-1} recorded the highest number of filled grains and the lowest number of unfilled grains panicle^{-1}, being at a par without significant differences with the recommended dose of calcium super-phosphate as a standard basal application which ranked the first regarding to number of filled grains and the last regarding to unfilled grains panicle^{-1}.

Such increase in panicle length, panicle weight, number of filled grains panicle^{-1} and 1000-grain weight could be due to the effect of increased root biomass through cell division and elongation. The high root biomass was improved the nutrient uptake, by exploiting more volume of soil, which resulted in more P leaf content that ensure high ATP content with high plant pigments content, resulted in a larger photosynthesis, and optimum vegetative growth with higher net assimilation at pre and post heading, reflected in taller and heavier panicles with better grain filling and heavier grains. These observations confirm the findings of (Whitelaw 2000 and Zayed *et al.* 2010).

Another approach for extra phosphorus application is during the flowering and fruiting stages. During the transition from grow to bloom (the early generative stage), a great deal of energy is diverted to flower production. So extra phosphorus which is being the component of ATP (the energy currency in the metabolic activities), helps to promote the development of additional flowering sites, especially during the early stages of flower production, and consequently increased flower sets, development of reproductive organs, pistil biomass, fertilization rate, grain formation and accumulation of starch and soluble carbohydrates in grains which resulted in increments in previous discussed traits.

Similar results were reported by Erel *et al.* (2016), where they noted that, increased P availability was accompanied by a continuous excess in pistil biomass, which is considered an important trait positively related to fertilization success and fruits (grains) formation. Furthermore, Hermans *et al.* (2006), pointed out that, under P deficiency starch and soluble carbohydrates are expected to accumulate in the source organs (leaves) and diminish in the sink organs (grains) and vise versa.

Data documented in Table 8 clarified that, the tested phosphorus treatments had a highly significant positive effect on 1000-grains weight and grain yield under both soil types in 2017 and 2018 seasons. The trend of data for these two traits were typically matching with those obtained for panicle length, panicle weight and number of filled grains panicle^{-1} under normal and saline soils, in both seasons. Where, increasing the applied rate of phosphoric acid from 3 up to 9 liters ha^{-1} led to significant increment for 1000-grains weight and grain yield reaching to the level of insignificant variation with the values of these traits that scored by the recommended dose of calcium super phosphate as a standard basal application which ranked first under both soil types in 2017 and 2018 seasons. On contrast, control treatments recorded the lowest weights for 1000 grains and grain yield.

Table 8. 1000-grains weight (g) and grain yield (t ha^{-1}) for Giza 178 rice cultivar' plants as affected by the studied phosphorus treatments, under normal and saline soils in 2017 and 2018 seasons.

Characters	1000-grains weight (g)				Grain yield (t ha^{-1})			
Season	2017		2018		2017		2018	
Soil	Normal	Saline	Normal	Saline	Normal	Saline	Normal	Saline
Control	20.53^{c}	19.14^{d}	20.40^{c}	19.07^{d}	9.32^{c}	4.20^{c}	9.45^{c}	4.35^{c}
3 liters H_3PO_4 ha^{-1}	21.80^{b}	20.30^{c}	21.57^{b}	20.60^{c}	9.65^{c}	4.67^{b}	9.62^{c}	4.85^{b}
6 liters H_3PO_4 ha^{-1}	21.83^{b}	21.29^{b}	21.58^{b}	21.03^{b}	10.09^{b}	5.00^{b}	10.07^{b}	5.16^{b}
9 liters H_3PO_4 ha^{-1}	22.57^{a}	22.59^{a}	22.47^{a}	22.36^{a}	10.48^{a}	5.57^{a}	10.50^{a}	5.57^{a}
basal 37.5 kg P_2O_5 ha^{-1}	22.77^{a}	22.70^{a}	22.53^{a}	22.57^{a}	10.67^{a}	5.85^{a}	10.73^{a}	5.80^{a}
F-Test	**	**	*	**	**	**	**	**

Means designated by the same letter in the same column are not significantly different a according to Duncan's Multiple Range Test.
*, ** and N.S. indicate $P < 0.05$, $P < 0.01$ and not significant, respectively.

Phosphorous application whether a basal or a spray increased significantly chlorophyll content in rice, contributing to higher photosynthetic rate. Moreover, P application at late booting stage might increase some biochemical compounds such as RNA and DNA as well as the energetic compound *i.e.* NADP, FADP and ATP resulted in more cell division and elongation. Which leads to heavier and larger flag leaf, these large leaf area and heavy flag leaf with higher chlorophyll content perform photosynthesis better and produce more amount of photosynthetic metabolism which is transformed to the panicles, leading to higher yield components and finally higher yields.

These results are in the same line with those reported by Zayed *et al.* (2016) and Alam *et al.* (2009b) who found that, application of the recommended rate of P_2O_5 ha^{-1} gave the highest 1000 grain weight and grain yield. Also, Rashwan *et al.* (2019) noticed that, the recommended dose of phosphorus led to a huge canopy in addition to higher P uptake resulting in a high grain yield in wheat.

At the phosphorus level, the highest grain yield produced under the recommended standard basal application is more acceptable in the results context of (Julia *et al.* 2016), where they reported that root P uptake during grain filling contributes up to 70% of final grain P content. Also, Kwanho (2016) who noticed that, when exogenous P supply during grain filling is limited, the P demand of developing seeds necessitate premature remobilization of P from vegetative tissues, with consequent reductions in photosynthesis. However, the applied rates of phosphoric acid couldn't surpass the recommended standard basal application in grain yield and hardly be at a par with it only with spraying of the highest rate 9 liters ha^{-1}.

The grain yields produced under both normal and saline soils were dramatically varied; an extreme reduction in grain yield was noticed under saline soil compared to another normal soil in both seasons. This variation may be due to the enhanced uptake of (Na^+) and (Cl^-) ions under saline soil conditions that negatively affects crop growth and yield as a result of; the reduction in the uptake of essential nutrients such as phosphorus and potassium, low water use efficiency, toxic effects of Na^+ and Cl^- on plant morphological traits (root system size) and physiological reactions (activity of enzymes, the function of cell membranes and production of plant hormones) and high oxidative stress caused by high Na^+ and Cl^- levels. (Miransari, 2017).

Data in Table 9 indicated that, the tested phosphorus treatments had a highly significant positive effect on straw yield under saline soil in both seasons, while under normal soil; variations among means were not significant and only significant in 2017 and 2018 seasons, respectively.

The responses of straw yield to the tested phosphorus treatments varied under the studied soil types, where under normal soil conditions; there were no significant variations among the tested phosphorus treatments in 2017 season, whereas in 2018 season, only significant variations among the tested phosphorus treatments were found; the recommended dose of calcium super phosphate as a standard basal application ranked first and surpassed all rates of phosphoric acid and control treatment that all ranked the second without any significant difference among them.

On the other hand, under saline soil conditions, there were highly significant variations among the tested phosphorus treatments in both seasons, the recommended dose of calcium super phosphate as a standard basal application ranked first and recorded the highest straw yield with no significant differences with the rates of phosphoric acid 6 and 9 liters ha^{-1} in 2017 season and with only 9 liters ha^{-1} in the 2018 season. While, control treatments recorded the lowest straw yield, in both seasons.

Worthy to note that, under saline soil, application of phosphoric acid highly significantly increased straw yield compared to control. Also, raising the applied rates of the phosphoric acid from 3 up to 9 liters ha^{-1} led to highly significant increment in straw yield reaching to the first rank occupied by the basal application of the recommended phosphorus dose. However, under normal soil, different spraying rates of phosphoric acid did not accomplish any improvement in rice straw yield over control in both seasons, while the basal application of the recommended phosphorus dose achieved a slight significant improvement in the second season only. This trend may be due to the positive role of phosphorous application in alleviation of the harms caused by salinity, such as; reduction in photosynthesis due to decrease in leaf area, reduction in carbohydrates needed for growth, limitation of shoot and root growth, down-regulate shoot growth and disturbance in minerals supply. Whereas, there was no urgent need for this positive role of phosphorus under normal soil conditions, as these biochemical reactions were acted so close to its optimum rate.

It is noticeable that, the role of the tested phosphorus treatments was more clear, active, efficient and significant for grain yield in comparison to straw yield, that may due to phosphorus role during the flowering and fruiting stages in increasing flower sets, fertility, seed setting in panicles and forming the ATP energy compounds that provide the energy needed to carbohydrate metabolism and its movement to be stored in grains; in comparison with phosphorus limited role in vegetative growth that mainly demands and depends on the nitrogen element more than any other element.

Concerning to harvest index, it defines as the ratio of the harvested grain yield to biological yield (total biomass), so its data trend was almost similar to that obtained for grain yield, but the variations among means recorded by the tested phosphorus treatments were only significant under both of soils and seasons (Table 9). Control treatments recorded the lowest harvest index values. While, increasing the applied rate of phosphoric acid from 3 up to 9 liters ha^{-1} increased significantly harvest index, and its maximum values were recorded under the rate of 9 liters ha^{-1}, that did not significantly differ with the values recorded by the recommended dose of calcium super phosphate as a standard basal application. The more valuable role of phosphorus on grain yield in comparison to straw yield resulted in higher harvest index with the highest rate of phosphoric acid and the recommended dose of calcium super phosphate. Similar findings had been indicated by Alam *et al.* (2009a) and Rashwan *et al.* (2019).

Table 9. Straw yield t ha^{-1} and harvest index for Giza 178 rice cultivar' plants as affected by the studied phosphorus treatments, under normal and saline soils in 2017 and 2018 seasons.

Characters	Straw yield (t ha^{-1})				harvest index			
Season	2017		2018		2017		2018	
Soil	Normal	Saline	Normal	Saline	Normal	Saline	Normal	Saline
Control	12.00	5.73^{c}	12.27^{b}	5.60^{d}	0.437^{d}	0.423^{c}	0.435^{c}	0.437^{b}
3 liters H_3PO_4 ha^{-1}	12.08	6.12^{b}	12.37^{b}	6.27^{c}	0.444^{c}	0.433^{b}	0.437^{c}	0.436^{b}
6 liters H_3PO_4 ha^{-1}	12.17	6.57^{a}	12.53^{b}	6.61^{bc}	0.453^{b}	0.432^{b}	0.446^{b}	0.438^{b}
9 liters H_3PO_4 ha^{-1}	12.00	6.63^{a}	12.65^{b}	7.00^{ab}	0.466^{a}	0.457^{a}	0.454^{a}	0.443^{a}
Basal 37.5 kg P_2O_5 ha^{-1}	12.33	6.75^{a}	13.13^{a}	7.33^{a}	0.464^{a}	0.464^{a}	0.446^{a}	0.442^{a}
F-Test	N.S.	**	*	**	*	*	*	*

Means designated by the same letter are not significantly different a according to Duncan's Multiple Range Test.
*, ** and N.S. indicate $P < 0.05$, $P < 0.01$ and not significant, respectively.

Rice grain yield and economic evaluation:

Data listed in Tables 10 and 11 showed grain yield increase and production increase over control occurred by phosphorus treatments otherwise basal or foliar spray application in both seasons under couple of soils. The optimum increment in grain yield increase and production increase over control in L.E was produced by basal application of the recommended phosphorous dose followed by foliar spray with phosphoric acid at the rate of 9 liters H_3PO_4 ha^{-1} under both soils.

Table 10. Economic values of Giza 178 rice cultivar as affected by phosphorous treatments under normal and saline soils condition during 2017 and 2018 seasons.

Characters	Yield increase over control t ha^{-1}			
Season	2017		2018	
Soil	Normal	Saline	Normal	Saline
Control	-	-	-	-
3 liters H_3PO_4 ha^{-1}	0.33	0.47	0.17	0.50
6 liters H_3PO_4 ha^{-1}	0.77	0.08	0.62	0.81
9 liters H_3PO_4 ha^{-1}	1.16	1.37	1.05	1.22
Basal 37.5 kg P_2O_5 ha^{-1}	1.35	1.65	1.28	1.45

Table 11. Economic values of Giza 178 rice cultivar as affected by phosphorous treatments under normal and saline soils condition during 2017 and 2018 seasons

Characters	Production of yield increase over control L.E ha^{-1}				Cost of p applied L.E ha^{-1}
Season	2017		2018		-
Soil	Normal	Saline	Normal	Saline	-
Control	-	-	-	-	-
3 liters H_3PO_4 ha^{-1}	1419	2021	731	2150	135
6 liters H_3PO_4 ha^{-1}	3311	3440	2666	3483	270
9 liters H_3PO_4 ha^{-1}	4988	5891	4515	5246	405
Basal 37.5 kg P_2O_5 ha^{-1}	5805	7095	5504	6235	400

Average paddy rice price from 2017 to 2018= 4300 L.E / ton, 15L.E./ one kg of phosphoric acid and 80 L.E for 7.5kg P_2O_5

Table 12. Economic values of Giza 178 rice cultivar as affected by phosphorous treatments under normal and saline soils during 2017 and 2018 seasons.

Characters	Value/ cost ratio				Net return L.E ha^{-1}			
Season	2017		2018		2017		2018	
Soil	Normal	Saline	Normal	Saline	Normal	Saline	Normal	Saline
Control	-	-	-	-	-	-	-	-
3 liters H_3PO_4 ha^{-1}	10.5	14.9	5.41	15.9	1284	1886	596	2015
6 liters H_3PO_4 ha^{-1}	12.2	12.7	9.87	12.9	3428	3170	2396	2943
9 liters H_3PO_4 ha^{-1}	12.3	14.5	11.1	12.9	4583	5486	4110	4841
Basal 37.5 kg P_2O_5 ha^{-1}	14.5	17.7	13.7	15.5	5405	6695	4544	5835

Regarding the value/cost ratio, basal application of phosphorus surpassed phosphoric acid spray in both seasons under the two tested soils (Table12) under normal soil, 9 liters of phosphoric acid spray was the best regarding the value/cost ratio while under saline soil, 3 liters phosphoric acid spray recorded the highest values of value/cost ratio in both seasons. With respect to net return, it was noticed that, the basal application of recommended phosphorous support its high efficiency to produce the highest mean of net return in both seasons under the two types of soils followed by foliar spray of phosphoric acid at the rate of 9 liters ha^{-1}(Table12). Similar findings are recognized by Zayed *et al.* (2010 and 2011).

CONCLUSION

Proper methods of phosphorus fertilizer application basing on soil are very important to reduce phosphorus losses as well as increase the efficiency use of phosphorus by rice crop. Using phosphoric acid thrice at the rate of 9 liters H_3PO_4 ha^{-1} at mid tillering, panicle initiation and mid booting stages was equivalent to the recommended dose of calcium super-phosphate as a standard basal application under normal and saline soils for most studied traits. On the whole, the use of phosphoric acid represents a step forward to solve the phosphorus deficiency problem that may appear after transplanting rice plants by spraying at the rate of 9 L ha^{-1}, especially under saline soil conditions, where the problem of phosphate precipitation with calcium are more widespread.

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