

## **AN ATTEMPT TO INCREASE THE QUANTITY OF OIL IN MAIZE GROWN UNDER SALINE SOILS BY USING DIFFERENT FERTILIZATION TREATMENTS**

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### **ABSTRACT**

The main objective of this study was to use different fertilization methods and rates to increase the quantity of oil in maize per unit area to contribute to filling part of the gap in edible oils. Two field experiments were conducted, at El-Serw Agriculture Research Station, Agriculture Research Centre, Damietta Governorate, to demonstrate the effect of two methods of phosphorous fertilization (foliar and soil applied) & five nitrogen fertilization rates (0, 95, 190, 286 and 381 kg N ha<sup>-1</sup>) & their interaction on grain, stover yields and some chemical composition of maize in 2020 & 2021 seasons. The obtained results indicated that use of phosphorous foliar fertilization increased grain and stover yields by 41.2 and 38.07%, respectively. As well as, grain protein and oil yields were increased by 54.89 and 80.6% respectively. It also showed that applying 381 kg N ha<sup>-1</sup> increased grain & stover yields by 251.28 and 197.34%, respectively. As well as protein and oil yields were increased by 621.15 and 322.07%, respectively, as compared to control without apply phosphate or nitrogen fertilizer. These treatments gave good results in increasing the quantity of oil per unit area, which was the main purpose of the research. While maximizing the use of saline soil for this purpose. The foliar phosphorous treatment also led to an increase in the efficiency of nitrogen utilization with all nitrogen fertilization rates. Thus, utilizing huge regions with a high salinity of soil and irrigation water in the cultivation of an economic crop such as maize to produce grains and oil contribute to filling part of the gap in edible oils, as well as stover to manufacture silage for animal feeding.

**Key Words:** Maize, nitrogen, phosphorus, foliar spray, salt stress, fertilization efficiencies, oil quantity.

### **INTRODUCTION**

There is ample research shows that nutrients enter the above-ground portion of plants (usually the leaves) and supply at least part of their nutritional requirements. Several reports of micronutrient deficiencies being alleviated with foliar sprays encouraged such an

approach with nitrogen, phosphorus and potassium. Although some yield increases were achieved, in most cases the greater total nutrient requirement of macronutrients and problems with leaf injury when rates were raised to the needed levels made foliar application impractical. Some soils exhibit characteristics such as low or high pH, the presence of poorly available minerals, or have been subjected to nutrient-depleting processes (erosion, leaching, etc.) (Rengel, 2015). As a result, nutrient deficiency has become a worldwide problem (Fageria *et al.*, 2008). In addition, mineral P resources will be depleted in the near future, posing an even greater problem in agriculture (Raboy, 2013). Excessive P fertilization, on the other hand, is undesirable because P is a limited, nonrenewable resource (Schoumans *et al.*, 2015 and Mew 2016), and diffuse P losses from overly fertilized fields are a major cause of eutrophication in surface waters (Buczko and Kuchenbuch 2007). Also, the efficiency of absorption of nutrients such as nitrogen and phosphorous decreases in saline soils.

Maize (*Zea mays* L.), a C4 metabolism plant, is a major grain crop that provides basic food and/or oil for humans and cattle around the world. Maize is typically salt-tolerant and characterized as moderately sensitive to salinity, with germination and seedling establishment being more sensitive to saltwater than later developmental phases (Katerji *et al.*, 1994). Plant uptake of nitrogen (N), potassium (K), calcium (Ca), magnesium (Mg), and iron (Fe) is reduced by high rhizosphere sodium (Na) and chlorine (Cl). Low grain production in maize under salt stress is due to reduced grain weight and quantity (Farooq *et al.*, 2015). Salinity is a major issue that has a significant impact on maize production (Qayyum *et al.*, 2016). When the soil salinity increased from 3.8 to 7.4 dS ml in the third crop rotation year, maize grain yield decreased by 34% (Cucci *et al.*, 2019). Furthermore, an increase in the salt of irrigation water has a negative impact on plants, particularly maize. The use of salt-water to irrigate maize resulted in lower yields (Feng *et al.*, 2017 and Huang *et al.*, 2019).

Nitrogen (N) is a key nutrient for crop production that is commonly supplied in significant quantity to soils (Singh *et al.*, 2007 and Wei-Dong *et al.*, 2008). Mineral nitrogen fertilization improves growth, biomass, and yield, as well as facilitates metabolism, resulting in higher protein content in maize plant tissue (Lucas *et al.*, 2019 and Mosaad *et al.*, 2020). Nitrogen has a direct impact on protein amino acid composition and, as a result, the nutritional quality of economic production. Excessive salt harms plants by interfering with the uptake of competing nutrients and disrupting the uptake of water into the roots (David, 2007). Ammonification was slowed as salinity levels increased, but it was not fully stopped. Because nitrification was inhibited by both the quantity of salt and the type of amendment supplied to the soil, the

quantity of mineral N that accumulated was generally lowered as salinity increased (Zeng *et al.*, 2016).

Therefore, it is necessary to search for other methods of phosphate fertilization that promote and maintain an adequate supply of the plant's nutrients. One of the most important ways to add nutrients to plants is foliar spraying. The advantage of foliar phosphorus spraying over in-soil application is that because leaf tissue has the same morphological structure as root tissue (it both originate from the meristem tissue), plants can rapidly absorb dissolved minerals (Martinka *et al.*, 2014). Foliar fertilizing can thus successfully manage soil deficiency in micro-elements (Barbosa *et al.*, 2013 and Tejada *et al.*, 2018).

The present study was carried out in the northern Delta of Egypt to see how phosphorous addition methods affected nitrogen fertilization efficiency, grain production, and oil quality characteristics of maize under salt stress. The hypotheses were that: (i) maize requires more fertilizer N and P for maximum yield than the recommended rate, (ii) this quantity rises as soil salinity and pH rise, and (iii) changing the traditional method of fertilizing with one of the two components has a greater effect on the economic maize crop and oil under salinity stress.

## MATERIAL AND METHODS

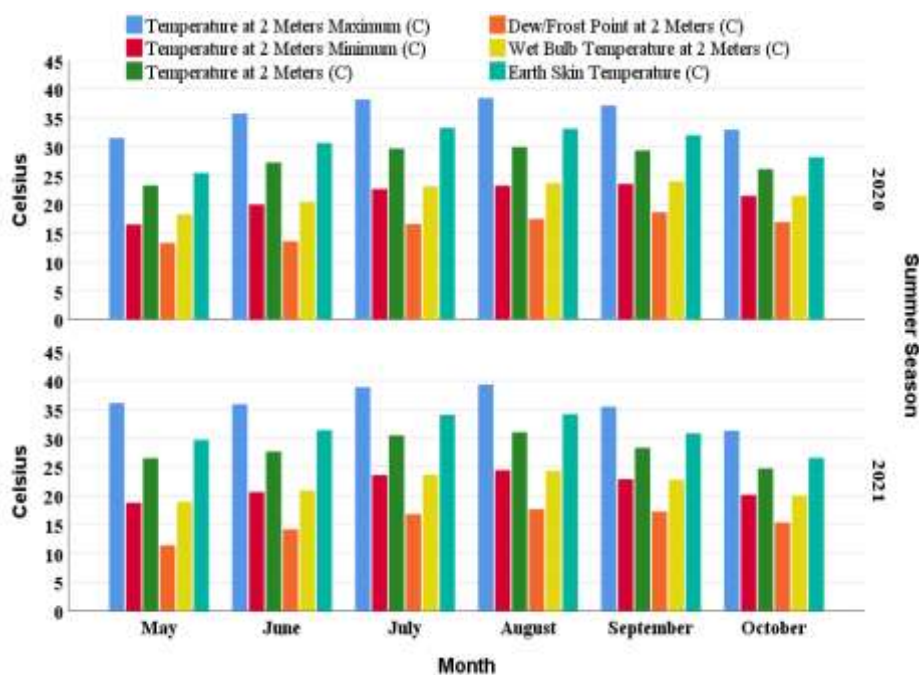
### Description of the experimental site and climate

At El-Serw Agriculture Research Station, Agriculture Research Centre, Damietta Governorate (31° 14' N and 31° 48' E) in northern Egypt, field experiments were conducted on clayey soil for two summer seasons (2020 and 2021). At the start of the experiments, the analyses of the surface soil layer (0 to 30 cm) were as follows: soil saturation extract for EC analysis (EC<sub>e</sub>) 8.77 dS m<sup>-1</sup> with pH (H<sub>2</sub>O, 1 soil to 2.5 H<sub>2</sub>O) value of 8.2 and contained 6.1 g kg<sup>-1</sup> walkley-black carbon, 0.30 g kg<sup>-1</sup> total nitrogen by the Kjeldahl method (Nelson and Sommers 1980), 7.93 mg kg<sup>-1</sup> 0.5 M NaHCO<sub>3</sub>-extractable P (Olsen *et al.*, 1954) and 422 mg kg<sup>-1</sup> 1 N NH<sub>4</sub>OAc-extractable K (Jackson, 2005). The soil study experiment was classified as moderately saline soil (EC<sub>e</sub> 8-16 dS/m) based on the USDA classes (Richards, 1954). The experimental farm was irrigated from the El-Serw drainage, irrigated from a point at the beginning of the drainage was approximately 20 km (EC 3.2:3.3 dS m<sup>-1</sup>, SAR 10.5:11.3), so the irrigation water classification is considered to be water which increases salinity problems (Tagour and Mosaad 2017 ; Mosaad *et al.*, 2020). The area has an arid climate with dry hot summer and wet cool winter according to the Köppen climate classification (Messina, 2019). Meteorological conditions (mean Precipitation (mm), Surface Pressure (kPa), Relative Humidity (%) and Wind Speed (m s<sup>-1</sup>) (Table 1), and maximum, minimum, and mean Temperature, dew/forest

point, Wet Bulb and Earth Skin Temperature ( $^{\circ}\text{C}$ ) at the maize cultivation experimental site during the two summer seasons (Fig. 1).

**Table 1. Average Precipitation Corrected (mm), Surface Pressure (kPa), Relative Humidity (%) and Wind Speed Range ( $\text{m s}^{-1}$ ) of experimental site during summer seasons 2020 and 2021.**

Month	Precipitation Corrected (mm)		Surface Pressure (kPa)		Relative Humidity (%)		Wind Speed Range ( $\text{m s}^{-1}$ )	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
2020								
May	0.01	0.02	101.30	0.31	60.15	6.40	3.15	0.95
June	0.00	0.01	100.99	0.23	49.90	5.89	3.34	0.77
July	0.00	0.00	100.60	0.18	51.85	3.16	3.15	0.55
August	0.00	0.00	100.62	0.14	53.80	2.94	3.04	0.50
September	0.00	0.00	101.01	0.25	58.18	4.06	2.93	0.52
October	0.04	0.11	101.43	0.18	61.33	2.72	2.72	0.41
2021								
May	0.00	0.00	101.15	0.17	47.44	6.04	3.07	0.69
June	0.00	0.00	101.14	0.26	49.66	3.36	3.20	0.50
July	0.00	0.00	100.63	0.18	50.15	3.53	3.15	0.79
August	0.03	0.06	100.73	0.18	51.94	4.77	2.70	0.62
September	0.05	0.11	101.09	0.18	55.27	3.79	3.26	0.49
October	0.18	0.61	101.47	0.28	59.66	4.16	2.89	0.54



**Fig. 1.** Maximum, Minimum and Main Temperature, Dew/Forest Point, Wet Bulb and Earth Skin Temperature ( $^{\circ}\text{C}$ ) of experimental site during summer seasons 2020 and 2021.

### Experimental treatments and crop management

A split-plot design with four replicates were used where the main plots were arranged to study the effect of phosphorous addition methods to evaluate the foliar and -soil P applied. Foliar phosphorus was applied at 144 mM  $\text{KH}_2\text{PO}_4$  at a rate of 460 L  $\text{ha}^{-1}$  (Rafiullah *et al.*, 2018 & 2020) and, it was sprayed at the knee-height (Zadocs-32) + tasseling (Zadocs-65) stage to maize. While the soil addition of phosphorus was applied at the recommended rate of 36 kg P  $\text{ha}^{-1}$  as Triple Calcium Super Phosphate (16.4% P) before maize cultivation. Mineral nitrogen fertilization rates were 0, 95, 190, 286 and 381 kg N  $\text{ha}^{-1}$  as ammonium nitrate (33.5% N) occupied in the subplots. The plot was 16  $\text{m}^2$  (4m  $\times$  4m) in size and had four ridges (4m long and 50 cm apart). On May 3<sup>rd</sup>, maize (*Zea mays* L.), variety, single cross 30K8, was sown at 28.6 kg grain  $\text{ha}^{-1}$ . In both seasons, maize grains were planted on 25 cm apart on one side with two kernels and hand-planted per hill and thinned to one plant per hill before the first irrigation. Other agricultural practices recommended for the region were carried out.

### Maize characteristics and crop yields

Maize was harvested at physiological maturity on October 5<sup>th</sup> in both seasons. For yield measurement, a net plot area of 4m  $\times$  4m was harvested manually and grains from the ears were manually removed. Grain and stover yields of maize were reported at 14% moisture content and on an oven-dry weight basis.

### Plant and grain analysis

Sub-samples of maize grain and stover were oven-dried at 65 °C for 48 h to a constant weight and ground to pass through a 0.5mm screen. Total N content was determined by Micro-Kjeldahl method (Westerman 1991).

Grain protein content was estimated by multiplying N (%) in maize grains  $\times$  5.65.

Oil percentage in the grains were determined by extracting using a Soxhlet apparatus according to the method described by AOAC, (2005).

Nitrogen use efficiencies agronomic efficiency (AE) (kg grain/kg N applied), physiological efficiency (PE) (kg grain/kg N uptake) and apparent recovery efficiency (RE) (%) of added fertilizer N were calculated as:

$$\text{AE} = (\text{grain yield in N fertilized plot} - \text{grain yield in no N plot}) / (\text{quantity of N fertilizer applied in N fertilized plot})$$

$$\text{PE} = (\text{grain yield in N fertilized plot} - \text{grain yield in no N plot}) / (\text{total N uptake in N fertilized plot} - \text{total N uptake in no N plot})$$

$$\text{RE} (\%) = [(\text{total N uptake in N fertilized plot} - \text{total N uptake in no N plot}) / (\text{quantity of N fertilizer applied in N fertilized plot})] \times 100$$

### The statistical analysis

Data were collected for statistical analysis according to (Snedecor and Cochran 1989). Mean values were compared, at a level of  $P < 0.05$  by using the Least Significance Difference (LSD) test. CoStat (v. 6.400 CoHort software, California, USA) and SPSS (v. 26, IBM Inc., Chicago, IL, USA) were used for statistical analysis for data.

## RESULTS AND DISCUSSION

### Maize grain and stover yield:

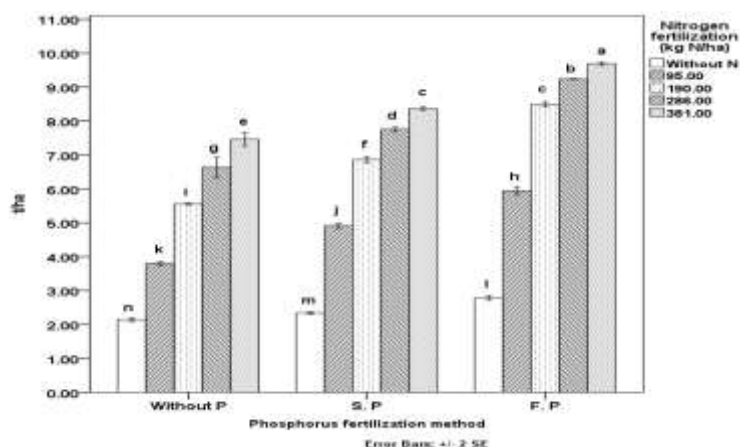
The maize grain and stover were affected by phosphorus fertilization method & nitrogen fertilization rates factors & their interaction in 2020 & 2021 summer seasons and their pooled analysis (Table 2 and Figs 2 & 3). Data in Table 2 showed that the effect of the phosphorus fertilization method and nitrogen fertilization rates and their interaction were significantly ( $P < 0.01$ ) on maize grain yield in both seasons and the pooled analysis. While, the effect of phosphorus fertilization method was significant ( $P < 0.05$ ) on maize stover yield in the first season and the pooled analysis. The influence of nitrogen fertilization rates and the interaction effect were significant ( $P < 0.01$ ) on maize stover yield in the second season and the pooled analysis. As for the factor of phosphorous fertilization methods, the highest results of the grain and stover yields were obtained with the application of phosphorus fertilization by foliar, followed by ground phosphorous fertilization. The grain yield of maize in the pooled analysis increased due to foliar phosphorus fertilization and soil phosphorus fertilization compared to without phosphorus by 41.2 and 18.08%, respectively. While, stover yield increased due to foliar phosphorus fertilization and soil phosphorus fertilization compared to without phosphorus by 38.07 and 13.66%, respectively. On the other hand, the use of 318 kg ha<sup>-1</sup> followed by 286, 190 and 95 kg N ha<sup>-1</sup>, respectively gave the highest yields of maize grain and stover compared to the control treatment without nitrogen fertilization by (251.28 and 197.34%), (225.21 and 186.97%), (187.81 and 183.04%) and (101.69 and 98.20%), respectively. The interaction effect on maize grain yield (Fig 2) showed that the highest values obtained with (381 kg N ha<sup>-1</sup> + foliar phosphorus) followed by (286 kg N ha<sup>-1</sup> + foliar phosphorus) with a significant difference. The following increase was at (286 kg N ha<sup>-1</sup> + soil phosphorus) followed by (190 kg N ha<sup>-1</sup> + foliar phosphorus) with no significant difference. While, the interaction effect on maize stover yield (Fig 3) showed that the highest values obtained with (381 kg N ha<sup>-1</sup> + foliar phosphorus), (286 kg N ha<sup>-1</sup> + foliar phosphorus) and (190 kg N ha<sup>-1</sup> + foliar phosphorus), respectively with no significant differences.

One of the major challenges is the fixation of phosphatic fertilizers in alkaline soils, it causes phosphorus nutritional stress, which can reduce maize yield (Rafiullah *et al.*, 2020). In the pooled analysis, foliar phosphorus fertilization and soil phosphorus fertilization increased maize grain yield by 41.2 and 18.08 %, respectively, when compared to no phosphorus fertilization.

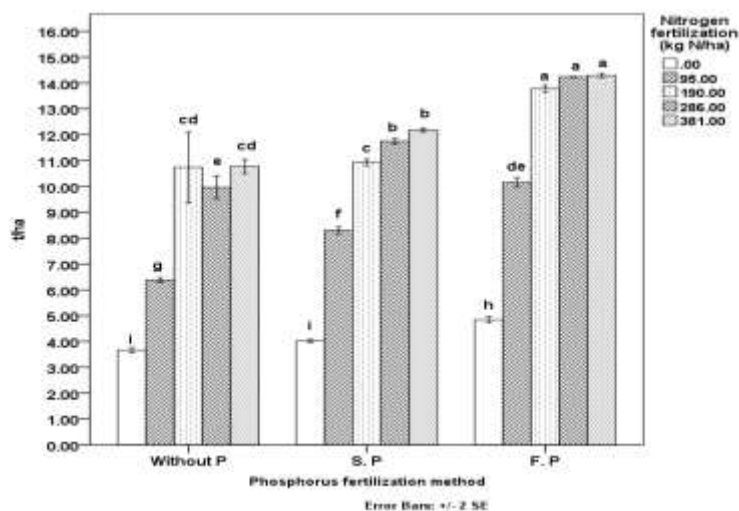
While foliar and soil phosphorus fertilization increased stover yield by 38.07 and 13.66 %, respectively, when compared to no phosphorus fertilization. Phosphorus increases plant growth development by taking part in the metabolic activity, enhanced photosynthetic process and photosynthate assimilation (Wahid *et al.*, 2019). These results are similar to those attributed by Rafiullah *et al.*, (2020), who found that foliar spray of phosphorus significantly enhanced grains yield of maize where phosphorus was applied as banding or broadcast at the time of sowing.

**Table 2: Means of maize grain and stover yield (t ha<sup>-1</sup>) as affected by phosphorous addition methods and nitrogen fertilization rates in 2020 & 2021 summer seasons.**

Treatment	Grain yield (t ha <sup>-1</sup> )			Stover yield (t ha <sup>-1</sup> )		
	1 <sup>st</sup>	2 <sup>nd</sup>	Pooled analysis	1 <sup>st</sup>	2 <sup>nd</sup>	Pooled analysis
<b>Phosphorus fertilization Method</b>						
Without P	5.079	5.153	5.116	8.599	8.004	8.301
S. P	6.025	6.057	6.041	9.359	9.511	9.435
F. P	7.192	7.256	7.224	11.356	11.565	11.461
Total	6.099	6.155	6.127	9.771	9.694	9.732
p value	0.020	0.000	0.006	0.039	0.004	0.013
<b>Nitrogen fertilization rates (kg N ha<sup>-1</sup>)</b>						
Without N	2.393	2.447	2.420	4.119	4.230	4.175
95.00	4.882	4.880	4.881	8.230	8.320	8.275
190.00	6.883	7.046	6.965	12.332	11.303	11.817
286.00	7.852	7.888	7.870	11.834	12.127	11.981
381.00	8.485	8.516	8.501	12.340	12.489	12.414
Total	6.099	6.155	6.127	9.771	9.694	9.732
p value	0.000	0.000	0.000	0.000	0.000	0.000
<b>P.M. × N</b>						
p value	0.000	0.000	0.000	0.000	0.000	0.000



**Fig. 2.** Pooled analysis of maize grain yield (t ha<sup>-1</sup>) affected by the interaction effect between phosphorous addition methods and nitrogen fertilization rates as soil-addition



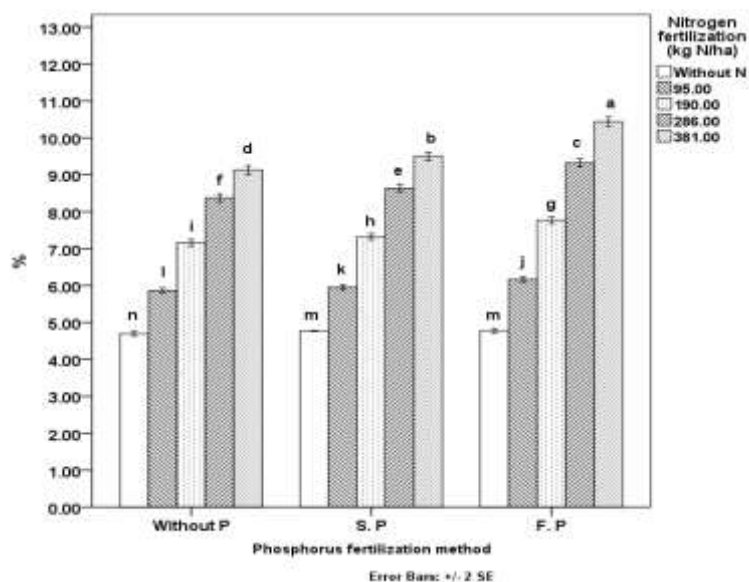
**Fig. 3.** Pooled analysis of maize stover yield ( $t\ ha^{-1}$ ) affected by the interaction effect between phosphorous addition methods and nitrogen fertilization rates as soil-addition

On the other hand, the rate of nitrogen application is an important management decision for maize (*Zea mays* L.) production (Davies *et al.*, 2020). The use of  $318\ kg\ N\ ha^{-1}$  followed by  $286$ ,  $190$  and  $95\ kg\ N\ ha^{-1}$ , respectively gave the highest yields of maize grain and stover compared to the control treatment without nitrogen fertilization by (251.28 and 197.34%), (225.21 and 186.97%), (187.81 and 183.04%) and (101.69 and 98.20%), respectively.

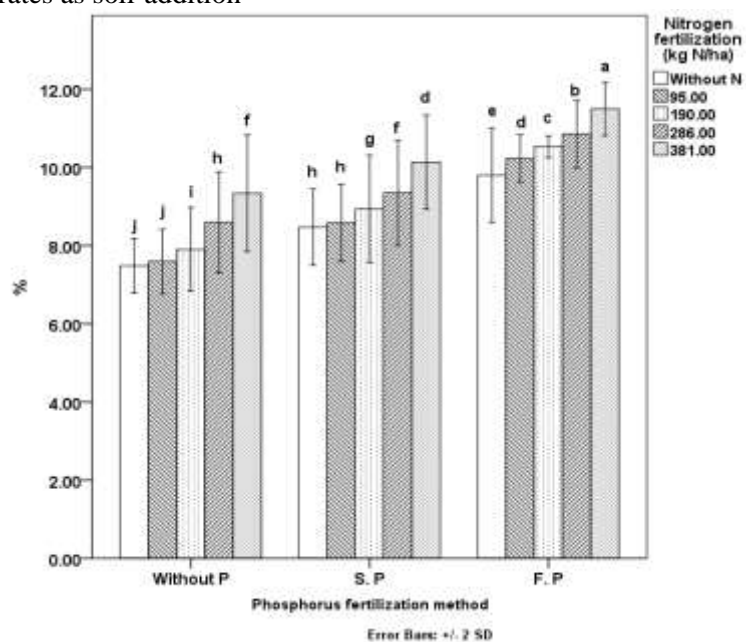
While the interaction effect on maize grain yield (Fig. 2) showed that the highest values obtained with ( $381\ kg\ N\ ha^{-1}$  + foliar phosphorus) followed by ( $286\ kg\ N\ ha^{-1}$  + foliar phosphorus) with a significant difference. The following increase was at ( $286\ kg\ N\ ha^{-1}$  + soil phosphorus) followed by ( $190\ kg\ N\ ha^{-1}$  + foliar phosphorus) with no significant difference. While, the interaction effect on maize stover yield (Fig. 3) showed that the highest values obtained with ( $381\ kg\ N\ ha^{-1}$  + foliar phosphorus), ( $286\ kg\ N\ ha^{-1}$  + foliar phosphorus) and ( $190\ kg\ N\ ha^{-1}$  + foliar phosphorus), respectively with no significant differences. Commercial fertilizers, particularly phosphorus and nitrogen fertilizers, are responsible for at least 30–50% of crop output in intensive cultivation of high-yielding crop varieties (Stewart *et al.*, 2005). This increase in the yield of maize grain and straw is due to the direct and indirect effect of nitrogen (Blumenthal *et al.*, 2008 and Mosaad *et al.*, 2020) & phosphorous (Zhang *et al.*, 2018 and Wahid *et al.*, 2019) on vegetative growth, such as an increase in leaf area and the positive effect on photosynthetic pigments, which results in an increase in yield.





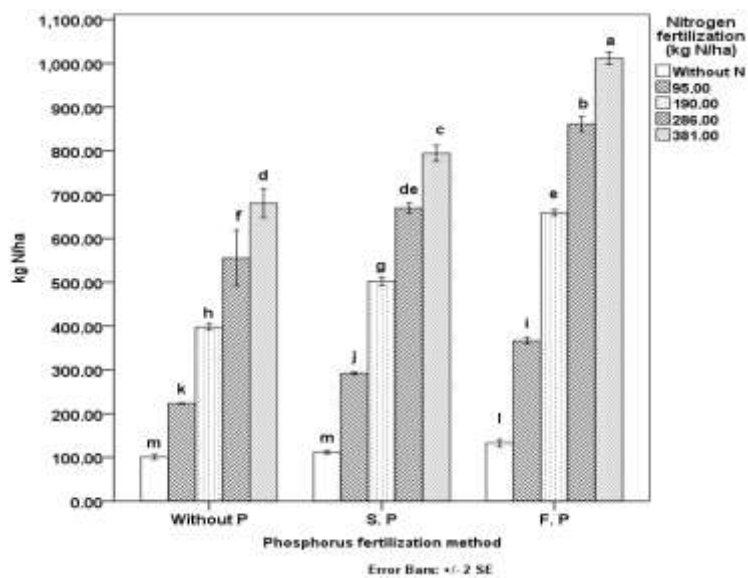


**Fig. 4.** Pooled analysis of maize grain protein% affected by the interaction effect between phosphorous addition methods and nitrogen fertilization rates as soil-addition

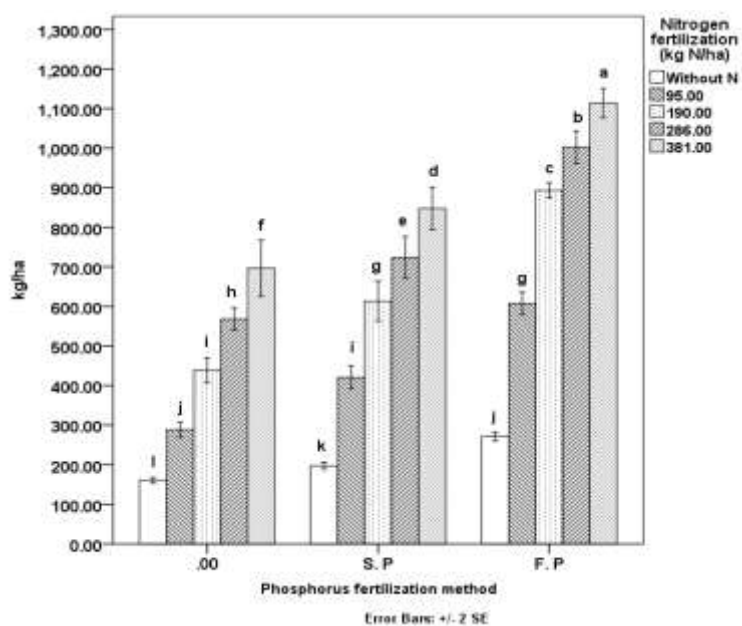


**Fig. 5.** Pooled analysis of maize grain oil% affected by the interaction effect between phosphorous addition methods and nitrogen fertilization rates as soil-addition





**Fig. 6.** Pooled analysis of maize grain protein yield ( $\text{kg ha}^{-1}$ ) affected by the interaction effect between phosphorous addition methods and nitrogen fertilization rates as soil-addition



**Fig. 7.** Pooled analysis of maize grain oil yield ( $\text{kg ha}^{-1}$ ) affected by the interaction effect between phosphorous addition methods and nitrogen fertilization rates as soil-addition

The interaction effect on maize protein yield (Fig 6) showed that the highest values obtained with (381 kg N ha<sup>-1</sup> + foliar phosphorus) followed by (286 kg N ha<sup>-1</sup> + foliar phosphorus), (381 kg N ha<sup>-1</sup> + soil phosphorus) and (381 kg N ha<sup>-1</sup> + without phosphorus), respectively with a significant difference. Also, it is noticed in Figure 6 that there are no significant differences between the effect of (381 kg N ha<sup>-1</sup> + without phosphorus) and (286 kg N ha<sup>-1</sup> + soil phosphorus) and between (286 kg N ha<sup>-1</sup> + soil phosphorus) and (190 kg N ha<sup>-1</sup> + foliar phosphorus) on the protein yield of maize.

While, the interaction effect on maize grain oil yield (Fig 7) showed that the highest values obtained with (381 kg N ha<sup>-1</sup> + foliar phosphorus) followed by (286 kg N ha<sup>-1</sup> + foliar phosphorus), (190 kg N ha<sup>-1</sup> + foliar phosphorus) and (381 kg N ha<sup>-1</sup> + soil phosphorus), respectively with a significant difference.

An adequate supply of nitrogen and phosphate fertilizers for maize plants is one of the determining factors for raising the protein and oil content of maize grains. In terms of phosphorus fertilization methods, the current research found that foliar phosphorus fertilization had the best outcomes in terms of protein and oil % in maize grain, followed by soil phosphorous fertilization. So, the protein yield of maize in the pooled analysis increased due to foliar phosphorus fertilization and soil phosphorus fertilization compared to without phosphorus by 54.89 and 21.1%, respectively. When compared to the control treatment without nitrogen fertilization, the application of 318 kg N ha<sup>-1</sup>, followed by 286, 190, and 95 kg N ha<sup>-1</sup>, yielded the highest values of maize protein and oil percentage, respectively, where it gave the highest yields of maize protein and oil compared to the control treatment without nitrogen fertilization by (621.15 and 322.07%), (504.99 and 264.39%), (352.05 and 208.93%) and (155.54 and 109.21%), respectively. The interaction effect on maize grain protein percentage revealed that the highest values were obtained with (381 kg N ha<sup>-1</sup> + foliar phosphorus), followed by (381 kg N ha<sup>-1</sup> + soil phosphorus), (286 kg N ha<sup>-1</sup> + foliar phosphorus), and (381 kg N ha<sup>-1</sup> + without phosphorus) with a significant difference. While the interaction effect on maize grain oil percentage revealed significant differences with (381 kg N ha<sup>-1</sup> + foliar phosphorus), (286 kg N ha<sup>-1</sup> + foliar phosphorus), and (190 kg N ha<sup>-1</sup> + foliar phosphorus). Furthermore, no significant differences in the effect of (381 kg N ha<sup>-1</sup> + soil phosphorus) and (95 kg N ha<sup>-1</sup> + foliar phosphorus) on the oil content of maize grains are observed. Higher biomass yields & protein yields and concentrations in plant tissue are often raised when nitrogen fertilizer is applied, because the amino acid composition of protein, and thus its nutritional quality, is frequently influenced by nitrogen (Blumenthal *et al.*, 2008). Also, the content of maize grains of protein

and oil increased when using 125% of the recommended rate of mineral fertilizers such as nitrogen and phosphorous (Ray *et al.*, 2019). Therefore, these increases in the protein and oil content of maize kernels are due to the adequate supply of nitrogen and phosphate fertilizers. The superiority of foliar fertilization of phosphorous is due to its superiority in the rapid supply of phosphorous than the soil fertilization, which causes soil properties to stabilize phosphorous before the plant can benefit from it (Fageria *et al.*, 2009, Rafiullah *et al.*, 2018).

#### **Nitrogen uptake of maize (kg N ha<sup>-1</sup>)**

Impact of phosphorus fertilization method & nitrogen fertilization rates factors and their interaction in 2020 & 2021 summer seasons and their pooled analysis on nitrogen uptake in maize grain, stover and total, are shown in Table 5 and Figs 8, 9 and 10. Data in Table 5 showed that the effect of phosphorus fertilization method and nitrogen fertilization rates and their interaction were significantly ( $P < 0.01$ ) on nitrogen uptake in maize grain, stover and total in both seasons and pooled analysis. As for the factor of phosphorous fertilization methods, the highest results of nitrogen uptake in maize grain, stover and the total obtained with application of phosphorus fertilization by foliar, followed by ground phosphorous fertilization. On the other hand, the highest nitrogen uptake in maize grain, stover and total values were obtained with 318 kg ha<sup>-1</sup> followed by 286, 190 and 95 kg N ha<sup>-1</sup>, respectively.

The interaction effect on nitrogen uptake in maize grain (Fig. 8) showed that the highest values obtained with (381 kg N ha<sup>-1</sup> + foliar phosphorus) followed by (286 kg N ha<sup>-1</sup> + foliar phosphorus), (381 kg N ha<sup>-1</sup> + soil phosphorus) and (381 kg N ha<sup>-1</sup> + without phosphorus), respectively with a significant difference. Also, it is noticed in Figure 8 that there are no significant differences between the effect of (381 kg N ha<sup>-1</sup> + without phosphorus) and (286 kg N ha<sup>-1</sup> + soil phosphorus) and between (286 kg N ha<sup>-1</sup> + soil phosphorus) and (190 kg N ha<sup>-1</sup> + foliar phosphorus) on the nitrogen uptake in maize grain.

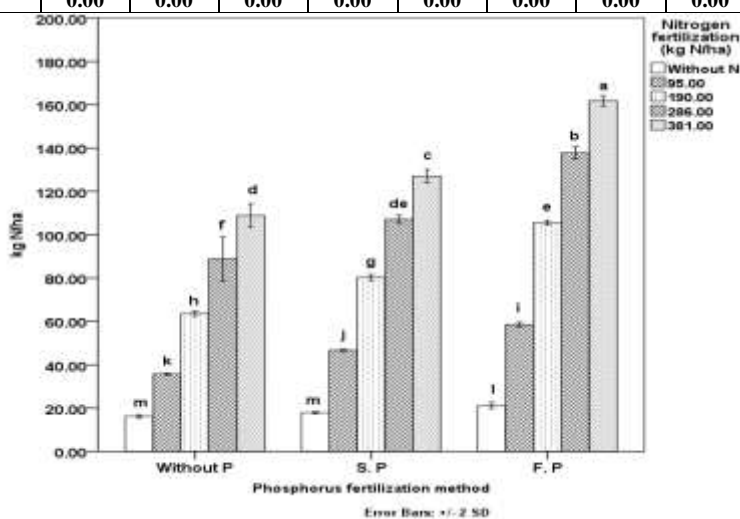
While, the interaction effect on nitrogen uptake in maize stover (Fig. 9) showed that the highest values obtained with (381 kg N ha<sup>-1</sup> + foliar phosphorus) followed by (286 kg N ha<sup>-1</sup> + foliar phosphorus), (381 kg N ha<sup>-1</sup> + soil phosphorus) and (286 kg N ha<sup>-1</sup> + foliar phosphorus), respectively with a significant difference. Also, in Figure 9, it is noticed that there are no significant differences between the effect of (381 kg N ha<sup>-1</sup> + without phosphorus) and (190 kg N ha<sup>-1</sup> + foliar phosphorus) on the nitrogen uptake in maize stover.

Total nitrogen uptake of maize (kg N ha<sup>-1</sup>) as affected by the interaction between phosphorus fertilization methods and nitrogen fertilization rates is shown in Fig 10. It showed that the highest values obtained with (381 kg N ha<sup>-1</sup> + foliar phosphorus) followed by (286 kg N ha<sup>-1</sup>

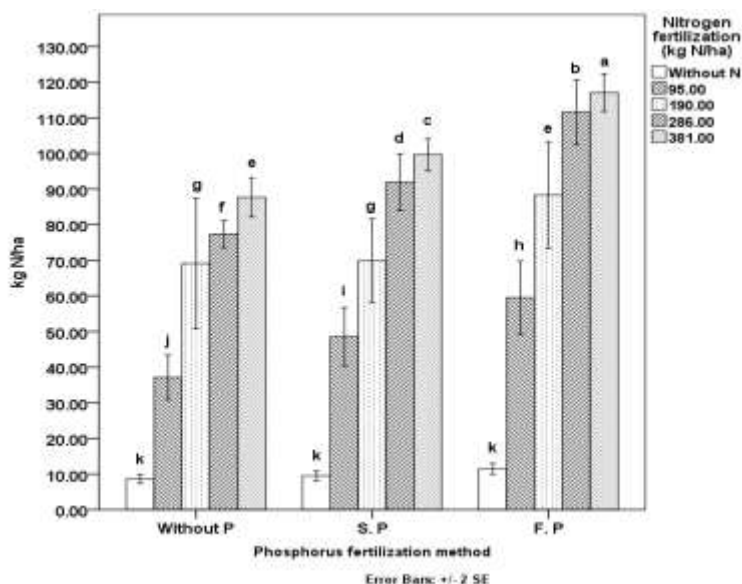
<sup>1</sup> + foliar phosphorus) and (381 kg N ha<sup>-1</sup> + soil phosphorus), respectively with a significant difference. Also, it is noticed in Figure 10 that there are no significant differences between the effect of (381 kg N ha<sup>-1</sup> + without phosphorus) and (286 kg N ha<sup>-1</sup> + soil phosphorus) and between (286 kg N ha<sup>-1</sup> + soil phosphorus) and (190 kg N ha<sup>-1</sup> + foliar phosphorus) on the total nitrogen uptake of maize.

**Table 5: Means of maize grain and stover nitrogen uptake and total (kg N ha<sup>-1</sup>) as affected by phosphorous addition methods and nitrogen fertilization rates in 2020 & 2021 summer seasons.**

Treatment	Grain N-Uptake (kg N ha <sup>-1</sup> )			Stover N-Uptake (kg N ha <sup>-1</sup> )			Total N-Uptake (kg N ha <sup>-1</sup> )		
	1 <sup>st</sup>	2 <sup>nd</sup>	Pooled analysis	1 <sup>st</sup>	2 <sup>nd</sup>	Pooled analysis	1 <sup>st</sup>	2 <sup>nd</sup>	Pooled analysis
<b>Phosphorus fertilization Method</b>									
Without P	60.65	64.59	62.62	57.42	54.56	55.99	118.07	119.15	118.61
S. P	74.36	77.28	75.82	62.60	65.18	63.89	136.95	142.47	139.71
F. P	94.63	99.34	96.99	76.00	79.16	77.58	170.63	178.50	174.57
Total	76.55	80.41	78.48	65.34	66.30	65.82	141.89	146.71	144.30
p value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Nitrogen fertilization rates (kg N ha<sup>-1</sup>)</b>									
Without N	17.87	18.92	18.40	9.64	10.12	9.88	27.51	29.04	28.28
95.00	46.03	47.94	46.99	47.55	49.22	48.39	93.58	97.16	95.37
190.00	80.48	85.81	83.14	78.50	73.03	75.76	158.98	158.84	158.91
286.00	108.70	113.77	111.24	91.37	95.87	93.62	200.07	209.64	204.86
381.00	129.65	135.59	132.62	99.64	103.27	101.45	229.28	238.86	234.07
Total	76.55	80.41	78.48	65.34	66.30	65.82	141.89	146.71	144.30
p value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>P.M. × N</b>									
p value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00



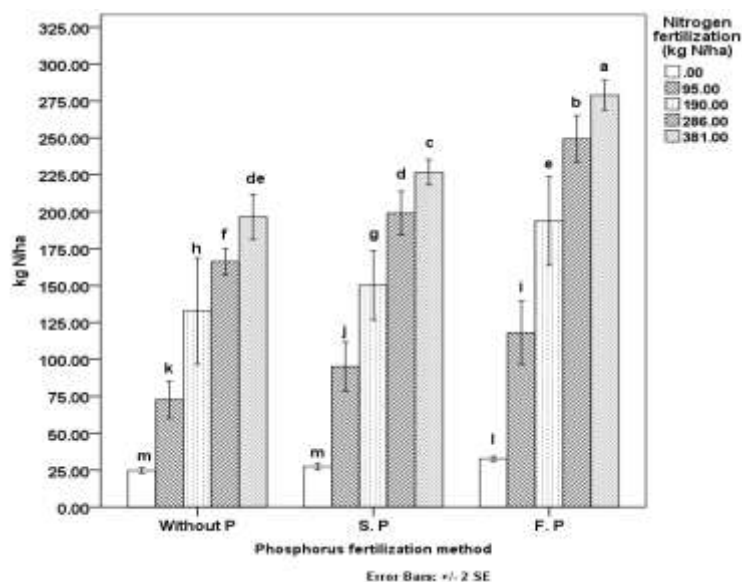
**Fig. 8.** Pooled analysis of maize grain nitrogen uptake (kg N ha<sup>-1</sup>) affected by the interaction effect between phosphorous addition methods and nitrogen fertilization rates as soil-addition



**Fig. 9.** Pooled analysis of maize stover nitrogen uptake ( $\text{kg N ha}^{-1}$ ) affected by the interaction effect between phosphorous addition methods and nitrogen fertilization rates as soil-addition

To explain the effect of phosphorous addition methods and nitrogen fertilization rates on total nitrogen uptake in maize, ( Fig 10). Total nitrogen uptake of maize ( $\text{kg N ha}^{-1}$ ) was significantly affected by the interaction between phosphorus fertilization methods and nitrogen fertilization rates, with the highest values obtained with ( $381 \text{ kg N ha}^{-1} + \text{foliar phosphorus}$ ), followed by ( $286 \text{ kg N ha}^{-1} + \text{foliar phosphorus}$ ) and ( $381 \text{ kg N ha}^{-1} + \text{soil phosphorus}$ ), respectively. There were no significant differences in total nitrogen uptake of maize between ( $381 \text{ kg N ha}^{-1} + \text{without phosphorus}$ ) and ( $286 \text{ kg N ha}^{-1} + \text{soil phosphorus}$ ) and between ( $286 \text{ kg N ha}^{-1} + \text{soil phosphorus}$ ) and ( $190 \text{ kg N ha}^{-1} + \text{foliar phosphorus}$ ). Thus, it is clear that the foliar treatment with phosphorous was superior to the in-soil method on the uptake of total nitrogen in maize. The advantage of foliar phosphorus spraying over in-soil application is that because leaf tissue has the same morphological structure as root tissue (they both originate from the meristem tissue), plants can rapidly absorb dissolved minerals (Martinka *et al.*, 2014). Foliar fertilizing can thus successfully manage soil deficiency in micro-elements (Barbosa *et al.*, 2013 and Tejada *et al.*, 2018). Also, the superiority of the higher nitrogen rate over the total nitrogen uptake is due to the direct effect of increasing the concentration of nitrogen in living tissues, as well as the indirect effect on raising the yield of maize grain and stover (Shrestha *et al.*, 2018). Hammad *et al.*,(2017), showed that nitrogen concentrations in the stem and grain of maize increased linearly as N fertilizer rates were increased with irrigation water.





**Fig. 10.** Pooled analysis of total nitrogen uptake in maize ( $\text{kg N ha}^{-1}$ ) affected by the interaction effect between phosphorus addition methods and nitrogen fertilization rates as soil-addition

### Nitrogen use efficiencies

Data in Table 6 showed the effect of phosphorus fertilization method & nitrogen fertilization rates and their interaction were significantly ( $P < 0.01$ ) on agronomic efficiency ( $\text{kg grain/kg N applied}$ ), physiological efficiency ( $\text{kg grain/kg N uptake}$ ) & apparent recovery efficiency (%) of maize nitrogen in both seasons and pooled analysis. As for the factor of phosphorus fertilization methods, the highest results of nitrogen use efficiencies of maize (AE, PE and RE%) were obtained with the application of phosphorus fertilization by foliar, followed by soil phosphorus fertilization. On the other hand, the highest values of AE, PE and RE% obtained with  $95 \text{ kg ha}^{-1}$  followed by  $190$ ,  $286$  and  $381 \text{ kg N ha}^{-1}$ , respectively.

The interaction effect on agronomic nitrogen efficiency of maize (Fig 11) showed that the highest values obtained with ( $95 \text{ kg N ha}^{-1}$  + foliar phosphorus) followed by ( $190 \text{ kg N ha}^{-1}$  + foliar phosphorus), ( $95 \text{ kg N ha}^{-1}$  + soil phosphorus) and ( $190 \text{ kg N ha}^{-1}$  + soil phosphorus), respectively with a significant difference.

While the interaction effect on physiological nitrogen efficiency of maize (Fig 12) showed that the highest values obtained with ( $95 \text{ kg N ha}^{-1}$  + soil phosphorus) followed by ( $95 \text{ kg N ha}^{-1}$  + foliar phosphorus) with no significant difference. Also, in Figure 12, it is noticed that there were

no significant differences between the effect of (95 kg N ha<sup>-1</sup> + foliar phosphorus) and (190 kg N ha<sup>-1</sup> + soil phosphorus), as well as between (190 kg N ha<sup>-1</sup> + foliar phosphorus) and (95 kg N ha<sup>-1</sup> + without phosphorus), also, between (190 kg N ha<sup>-1</sup> + without phosphorus) and (286 kg N ha<sup>-1</sup> + without phosphorus), as well, between (286 kg N ha<sup>-1</sup> + without phosphorus) and (286 kg N ha<sup>-1</sup> + soil phosphorus), also, between (286 kg N ha<sup>-1</sup> + soil phosphorus) and (381 kg N ha<sup>-1</sup> + without phosphorus), between (381 kg N ha<sup>-1</sup> + without phosphorus) and (381 kg N ha<sup>-1</sup> + soil phosphorus) and also, between (381 kg N ha<sup>-1</sup> + soil phosphorus) and (286 kg N ha<sup>-1</sup> + foliar phosphorus) on physiological nitrogen efficiency of maize.

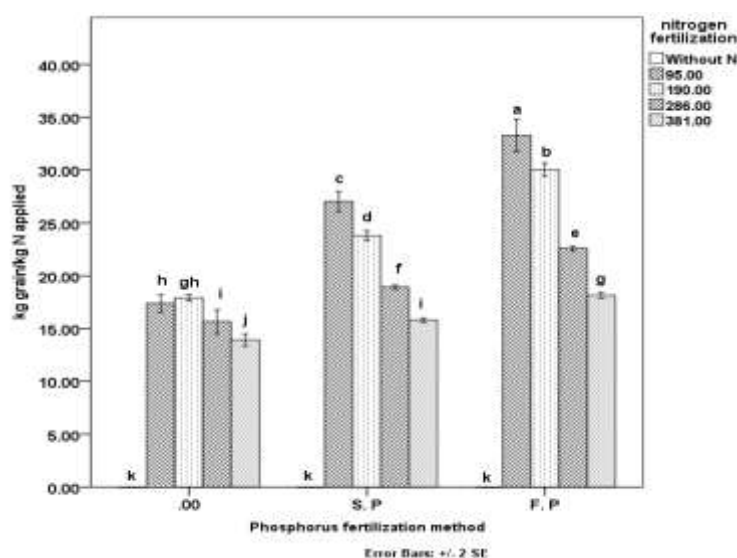
Apparent recovery efficiency (%) of maize nitrogen as affected by the interaction between phosphorus fertilization methods and nitrogen fertilization rates is shown in Fig 13. It showed that the highest values obtained with (95 kg N ha<sup>-1</sup> + foliar phosphorus) followed by (190 kg N ha<sup>-1</sup> + foliar phosphorus), (286 kg N ha<sup>-1</sup> + foliar phosphorus) and (381 kg N ha<sup>-1</sup> + soil phosphorus), respectively with a significant difference. Also, it is noticed in Figure 12 that there were no significant differences between the effect of (190 kg N ha<sup>-1</sup> + soil phosphorus) and (381 kg N ha<sup>-1</sup> + foliar phosphorus) and also, between (381 kg N ha<sup>-1</sup> + soil phosphorus) and (95 kg N ha<sup>-1</sup> + without phosphorus).

In terms of phosphorus fertilization methods, the highest nitrogen use efficiencies of maize (AE, PE, and RE %) were obtained with foliar phosphorus fertilization, followed by soil phosphorous fertilization. However, when it comes to nitrogen fertilization, the highest values of AE, PE, and RE % were obtained with 95 kg ha<sup>-1</sup>, followed by 190, 286, and 381 kg N ha<sup>-1</sup>, respectively. In general, a high PE indicated a nitrogen deficiency, whereas a low one indicated poor internal conversion (**Dobermann, 2007**). According to **Fageria et al., 2009**, applying fertilizer N in quantity greater than what is required to produce economic yields results in high N losses and low N use efficiencies (**Fageria et al., 2008**). Furthermore, the agronomic N use efficiency of maize decreased linearly as N levels increased, thus, the low N utilization efficiencies imply significant N losses or immobilization (**Lucas et al., 2019**). The top application of mineral N fertilizer most likely resulted in the majority of the mineral N fertilizer being found on or near the soil surface, with significant potential for N leaching and volatilization losses in this slightly alkaline soil (**Mosaad et al., 2020**). The results of the present study in this regard showed that the use of foliar fertilization with phosphorous with any level of nitrogen fertilization led to a higher use efficiency of nitrogen, and therefore it is recommended to use foliar fertilization with phosphorous so that there was no significant loss in

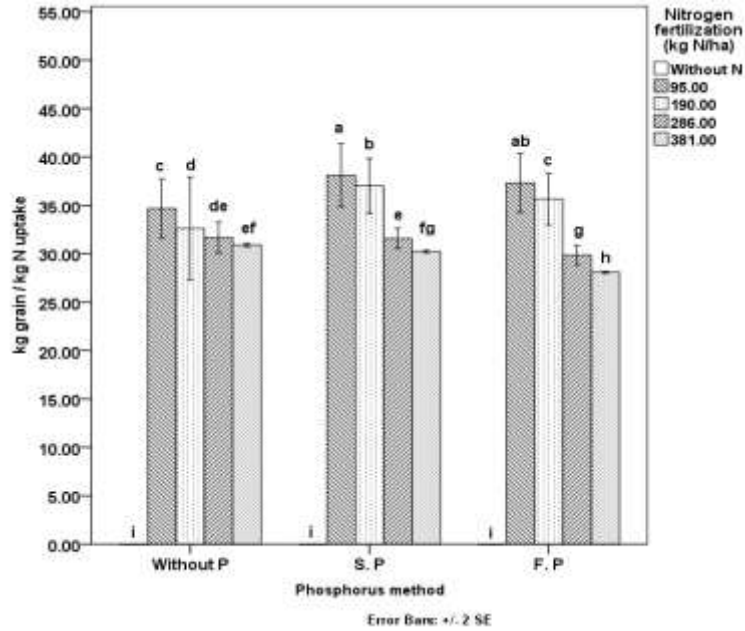
mineral nitrogen fertilization by raising the efficiency of maize to use nitrogen.

**Table 6: Means of maize Agronomic, Physiological and Apparent recovery efficiencies of nitrogen as affected by phosphorous addition methods and nitrogen fertilization rates in 2020 & 2021 summer seasons.**

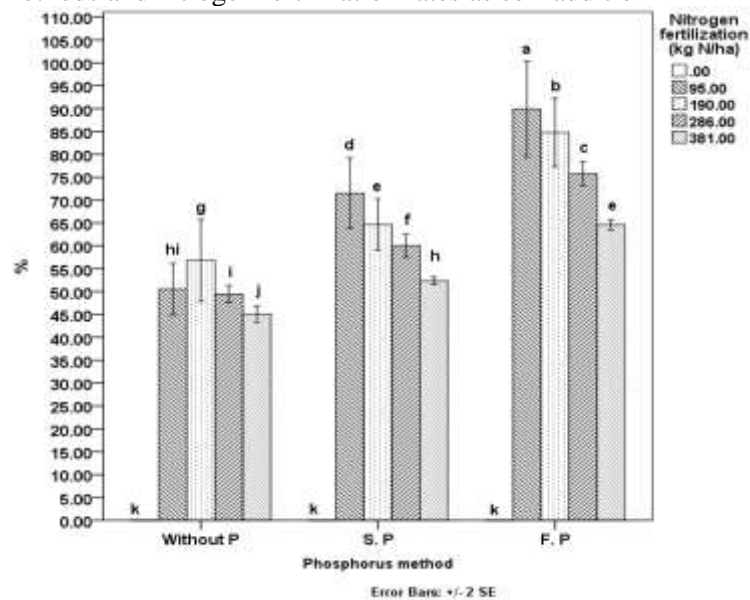
Treatment	Agronomic efficiency (AE) (kg grain/kg N applied)			Physiological efficiency (PE) (kg grain/kg N uptake)			Apparent recovery efficiency (RE) (%)		
	1 <sup>st</sup>	2 <sup>nd</sup>	Pooled analysis	1 <sup>st</sup>	2 <sup>nd</sup>	Pooled analysis	1 <sup>st</sup>	2 <sup>nd</sup>	Pooled analysis
<b>Phosphorus fertilization Method</b>									
Without P	12.942	13.014	12.978	25.894	26.046	25.970	40.770	39.984	40.377
S. P	17.114	17.115	17.114	27.896	26.864	27.380	48.753	50.640	49.697
F. P	20.889	20.738	20.813	26.836	25.525	26.181	61.700	64.318	63.009
Total	16.982	16.956	16.969	26.875	26.145	26.510	50.408	51.647	51.028
p value	0.000	0.000	0.000	0.009	0.000	0.002	0.000	0.000	0.000
<b>Nitrogen fertilization rates (kg N ha<sup>-1</sup>)</b>									
Without N	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
95.00	26.197	25.614	25.906	37.714	35.673	36.693	69.549	71.706	70.627
190.00	23.633	24.210	23.921	34.485	35.681	35.083	69.194	68.314	68.754
286.00	19.089	19.024	19.057	31.798	30.274	31.036	60.337	63.147	61.742
381.00	15.990	15.930	15.960	30.379	29.099	29.739	52.959	55.071	54.015
Total	16.982	16.956	16.969	26.875	26.145	26.510	50.408	51.647	51.028
p value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
<b>P.M. × N</b>									
p value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000



**Fig. 11** Pooled analysis of Agronomic nitrogen efficiency (kg grain kg N applied<sup>-1</sup>) affected by the interaction effect between phosphorous addition methods and nitrogen fertilization rates as soil-addition



**Fig. 12** Pooled analysis of Physiological nitrogen efficiency ( $\text{kg grain kg N uptake}^{-1}$ ) affected by the interaction effect between phosphorous addition methods and nitrogen fertilization rates as soil-addition



**Fig. 13:** Pooled analysis of Apparent nitrogen recovery (%) affected by the interaction effect between phosphorous addition methods and nitrogen fertilization rates as soil-addition

## CONCLUSIONS

The results of the current study showed that the foliar spraying of phosphorous led to an increase in the quantity of nitrogen uptake in maize grains & stover, and outperformed the soil treatment of phosphorous, thus raising the efficiency of nitrogen fertilization for maize grown in saline soil. Therefore, it could be recommend the use of foliar fertilization with phosphorous to increase the yield of grain and stover by 41.2 and 38.07%, respectively, as well as raise the grain protein and oil yield by 54.89 and 80.6%, respectively. Also using of 381 kg N ha<sup>-1</sup> to obtain a higher grain and stover yield by 251.28 and 197.34%, respectively, and a higher protein and oil yield by 621.15 and 322.07%, respectively, compared with the control treatments without phosphate and nitrogen fertilization. So, using 381 kg N ha<sup>-1</sup> + foliar phosphorus at 144 mM KH<sub>2</sub>PO<sub>4</sub> at a rate of 460 L ha<sup>-1</sup> to obtain the economic yield of maize grain, stover, protein, and oil under salinity stress. Thus, taking advantage of the vast areas that suffer from high salinity of soil and irrigation water in the cultivation of an economical crop such as maize, to produce grains and oil, and make use of stover to make silage for animals feeding.

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### محاولة زيادة كمية الزيت في الذرة المنزرع في الاراضي المتأثره بالملوحة

#### بواسطة معاملات التسميد المختلفة

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كان الهدف الاساسى من هذه الدراسه هو استخدام طرق ومعدلات تسميد مختلفه لزياده كميته الزيت في الذره من وحده المساحه للمساهمه في سد جزء من الفجوه في زيوت الطعام. لذلك تم إجراء تجربتين حقليتين بمحطة بحوث السرو الزراعيه ، مركز البحوث الزراعيه ، محافظة دمياط لبيان تأثير طريقتين للتسميد الفوسفاتي (رش على الأوراق وإضافة أرضية) وخمسة معدلات تسميد بالنيتروجين (0 ، 95 ، 190 ، 286 ، 381 كجم نتروجين/هكتار) وتفاعلها على محصول الحبوب والحبوب وبعض التركيب الكيمياءى للذرة في موسمي 2020 و 2021. أشارت النتائج المتحصل عليها إلى أن استخدام التسميد الورقي الفوسفاتي أدى إلى زيادة إنتاجية الحبوب والحبوب بنسبة 41.2 و 38.07% على التوالي ، وكذلك زيادة إنتاجية بروتين الحبوب والزيوت بنسبة 54.89 و 80.6%. كما بينت أن إضافة 381 كجم نتروجين/هكتار أدى إلى زيادة إنتاجية الحبوب والحبوب بنسبة 251.28 و 197.34% على التوالي ، وكذلك زيادة إنتاجية البروتين والزيوت بنسبة 621.15 و 322.07% على التوالي ، مقارنة بمعاملات المقارنة التي لم تستخدم فيها الفوسفات أو سماد نيتروجين. وقد اعطت هذه المعاملات نتائج جيده في زياده كميته الزيت لوحده المساحه مع تعظيم الاستفاده من الاراضى المتأثره بالاملاح لهذا الغرض. كما أدت المعالجة الورقية بالفوسفور إلى زيادة كفاءة الاستفاده من النيتروجين بكافه معدلات التسميد بالنيتروجين. وبالتالي ، الاستفاده من المناطق الشاسعة ذات الملوحة العاليه للتربة ومياه الري في زراعة محصول اقتصادي مثل الذرة لإنتاج الحبوب والزيوت للمساهمه في سد جزء من الفجوه في زيوت الطعام ، وكذلك الحبوب لتصنيع السيلاج لتغذية الحيوانات.