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Maize Yield and Quality as Influenced by Different Levels of Phosphorus and Sulphur

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ABSTRACT

Two field experiments were carried out on sandy soils atthe farm of El-Sharawy in EL-Bostan area, Noubariazone, Governorate of Elbeheira(Lat. 30° 43' 22.01" N, Longit. 30° 16' 44.50" E), Egypt, during two summer seasons of 2013 and 2014 on maize plants (c.v. tri- hybrid 354) to study the effects of phosphorus and sulphurapplication rates on yield and grain quality of maize. The experiment was laid out in a split plot design with three replications assigning phosphorus levels in the main plots and sulphur levels in sub-plots. The results of this study revealed that application of phosphorus and sulpher and their combinations had significant effects on most of the studied characters in favor of the combination treatment. Allthe studied characteristics except ear diameter were significantly increased by increasing both P and S fertilizers and the higher rate of 30 kg P_2O_5/fed or 150 kg S/fed. resulted in maximum plant height (2.82or 2.71m), cob weight (238 or 220 g), 100-grain weight (38.70 or 36.63g), grain yield (4473 or 4151 kg/ fed) and protein % (12.96 or 12.01) respectively as compared with the other rates . Application of P-fertilizer and sulpher in combination gave higher values and 30 kg P_2O_5 +150 kg S/fed. Surpassed the other combinations showing that application of 30 kg P_2O_5/fed + 150 kg S $fed^{-1}$is a good formula for achieving bettermaize crop with better quality.
Keywords: grain quality, maize, p-fertilizer, S-fertilizer, yield, yield components

INTRODUCTION

Maize (*Zea mays*, L) is a great important crop for both human and animal feeding. It ranks the third position among cereal crops. In Egypt, it is veryimportant to increase production of maize to cover gab between production and consumption. The highest maize yield production depends on many factors such as cultivars, phosphorus and sulphur fertilization.

Maize is also an exhaustive crop having higher potential than other cereals and absorbs large quantity of nutrients from the soil during different the growth stages. Among the essential nutrients, phosphorus is one of the most important nutrients for higher yield and quantity and controls mainly the reproductive growth of plant(Chaudhry*et al*., 2003). Plant growth behavior is influenced by the application of phosphorus (Hajabbasi and Schumacher,1994; Gill *et al*. 1995 and Kaya*et al*. 2001). It is needed for growth, utilization of sugar and starch, photosynthesis, nucleus formation and cell division, fat and albumen formation. Energy from photosynthesis and the metabolism of carbohydrates is stored in phosphate compounds for later use in growth and reproduction (Ayub*et al.* 2002). It is readily translocated within the plants, moving from older to younger tissues as the plant forms cells and develops roots, stems and leaves (Ali *et al.* 2002). Adequate P results in rapid growth and earlier maturity and improves the quality of vegetative growth. Phosphorus deficiency is responsible for crooked and missing rows as kernel twist and produce small ears nubbies in maize. The application of phosphatic fertilizers is considered essential for crop production and its deficiency will slow overall plant growth (Rashid and Memon, 2001).Ali *et al.* (2002) reported significant effect of P application on grain yield; whereas Ayub*et al.* (2002) observed significant effect of P application on dry matter yield and individual plant characteristics like height, number of leaves and leaf area.

Sulphur is the fourth major nutrient and plays an important role in the nutrition of oil-seed crop and as aconstituent of sulphur containing amino acids (Gangadhara*et al.* 1990),and its concentration and uptake vary with the availability of sulphur in soil.Singh (1999) reported that the application of sulphur increased the uptake of various macro and micro nutrientsin plant. Sharma and Gupta (1992) also reported that S fertilization up to 80 kg ha^{-1} significantly increasedthe uptake of N, P, K and S by soybean. Sulphur deficient plants have poor utilization of N, P, K and a significant reduction in sulphurcontent.The role of S in plants is to help in the formation of plant proteins, and it is essential for the formation ofchlorophyll and improves root growth. Sulphur is involved in the formation of vitamins and enzymes requiredfor the plant to conduct its biochemical processes (Scherer *et al.* 2008).Sulphur is accumulated in plants in low concentrations compared to N, but is an essential element asa constituent of proteins, cysteine-containing peptides such as glutathione, or numerous secondary metabolites(Scherer *et al.*, 2008 andAbdallah*et al*., 2010) and synthesis of vitamins and chlorophyll in the cell (Kacar andKatkat, 2007). The biochemical oxidation of S in soil produces H_2SO_4 which decreases soil pH and solubilizes $CaCO_3$in alkaline calcareous soils to make more favorable soil conditions for plantgrowth including the availability ofplant nutrients (Abdou, 2006). Erdal*et al*. (2006) reported that soil pH decreased with the application of S,resulting in increases in nutrient concentration, plant nutrient uptake, chlorophyll concentration, root nodulesand dry matter production. Similar results were also reported by Motior*et al.* (2011) who found that applicationof S significantly increased nutrient uptake and dry matter accumulation of maize in sandy soils.

The aim of the present investigation was to study the effect of P-fertilization rates and sulphur on growth, yield and its components as well as grain quality of maize.

MATERIALS AND METHODS

Scope and experimental site

Two field experiments were conducted on sandy soil atthe farm of El-Sharawy in EL-Bostanarea, Noubariazone, Governorate of Elbeheira (Lat. 30° 43'

22.01" N, Longit. 30° 16' 44.50" E), Egypt, duringthe two summer seasons of 2013 and 2014 on maize plants (c.v. tri- hybrid 354) to study the effects of phosphorus and sulphur application rates on yield and its components as well as grain quality of maize.

Treatments and experimental design

The experiment included 12 treatments, which were the combination between three levels of P fertilizers (0, 15 and 30 kg P_2O_5 fed^{-1}) and four levels of elemental sulphur (0, 50, 100 and 150 kg S /fed)laid out in a split plot design with three replications assigning phosphorus levels in the main plots and elemental sulphur levels in the sub plots. Randomized soil surface samples (0-30 cm) were collected from the siteof experiment atpre- sowing time to evaluate some physical-chemical properties using the standard methods reported by Page *et al.* (1982) and Klute (1986) as shown in Table (1).

Table 1. physical and chemical properties of the soils under investigation (average of two seasons).

Particle size distribution								
Coarse sand %	Fine sand %	Silt %	Clay %	Texture class	OM %	CaCO3 %	PH	EC (dS m^{-1})
52.2	39.3	5.4	3.1	Sand	0.16	3.5	8.1	4.1

Cations and anions in the soil paste extract, (meq /L)								available nutrients (mg kg-1)			
Cations				Anions							
Ca+2	Mg^{+2}	Na^{+}	K^{+}	$CO3^{-2}$	$HCO3^{-}$	Cl^{-}	$SO4^{-2}$	N	P	K	Zn
16.1	12.8	10.2	1.8	-	15.3	19.2	6.4	15	6.5	85	0.7

The sub plots area was $10.5m^2$, containing 5 ridges of 3m long and 70cm a part. The grains were drilled at 30cm apart and the plants were thinned to one plant /hill before first irrigation. Phosphorus fertilizer was applied as single calcium superphosphate (15 % P_2O_5) and sulphur as elemental S (98 % S)(application of S along withThiobacillus), both were added in one dose during land preparation before planting. Nitrogen fertilizer as ammonium nitrate (33.5% N), was added at the rate of 120 Kg N fed^{-1}. in three equal doses; before first, second and third irrigation. Potassium sulphate (48%K_2O) at the rate of 24kg K_2O fed^{-1}. was added in two equal doses, i.e.15 and 40 days after planting.At harvest time,sometraits were measuredas follows:

(a)Maize yield and some yield attributes:

Height of maize plant(cm), length of cob (cm), diameter of maize cob(cm), ear weight (g), number of $rowcob^{-1}$ and number of grains row^{-1},maize grain yield ($kgfed^{-1}$.) and weight of 100 grain (g)

(b) Chemical Constituents of grains:

Samples ofgrain were taken for the following chemical analysis:

- In the acid extract nitrogen content was determined by the micro Kjeldahl methodusing A.O.A.C. (2000). Grain protein content was estimated as N% x 5.75 on dry weight basis. Phosphorus content in grains was calorimetrically estimated using Chapman and Pratt, (1978)and Potassium was estimatedusing the flame photometer.
- Grain oil content was estimated by soxhelt apparatus using hexane as a solvent as described by A.O.A.C. (1980).
- Total soluble sugars were determined according to the method as described by Dubois *et al.,* (1956).Total carbohydrate in maize was also determined according to *Simith et al*.,[1956].Grain starch content was calculated bysubtracting soluble sugars from soluble carbohydrate. The experimental data obtained were subjected to analysis of variance (ANOVA), using the procedures outlined by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

I-Effect of different rates of phosphorus and sulphur on plant height and yield contributing characters of maize

The data presented in Table (2), showed that the entire studied parameters and grain yield were significantly increased by increasing the tested levels of both P and S fertilizers. The increasing trend of plant height was observed (from 2.42 to 2.71m) with the increasing level of sulphur from zero to 150 kg fed^{-1} but in case of phosphorus, plant height increased from 2.32 to 2.82m with the increasing level from 0 kgP_2O_5 fed^{-1} to 30 kg P_2O_5 fed^{-1} .The maximum plant height (2.91m) was recorded by $P_{30}S_{150}$ followed by $P_{30}S_{100}$ (2.86m) and $P_{30}S_{50}$ (2.79m) as compared to P_0S_0 (1.97m).
Similar trends were observed with ear characters (ear length, ear weight, row no. /ear and grain no./ear) as affected by both P and S treatments except eat diameter which was not significantly affected. Also, only ear weight was significantly affected by the interaction between P and S fertilization and 30 kg P2O5 +150 kg S/fed. recorded the heaviest ear (257 g/ear).

II:Grain yield and quality:

Perusal of data presented in Table (3) and Fig. (1-5), clearly demonstrated that grain yield varied significantly by P and S levels applied alone or in combination. Increased trend in yield was recorded up to 150 kg S or 30 kg P2O5 fed^{-1}. Yield increased from 3658to 4151 kg/fed. and from 3284to 4473kg/fed with increasing level of sulphur from zero to 150 kg $fed^{-1}$and phosphorus from 0 to 30 kg P_2O_5 fed^{-1}. In interactions, maximum yield of 4653 kg/fedwas recorded in $P_{30}S_{150}$ combination followed by $P_{30}S_{100}$ (4494 kg/fed) and $P_{30}S_{50}$ (4402kg/fed). The increase in grain yield of maize in sulphur applied plots might be due to higher production of metabolites and the increase in meristematic activity. Besides, it could be attributed to the improvement in nutritional environment in crop root zone and ultimately resulted in better vegetative growth and finally the grain yield. The increase in grain yield due to P fertilization could be attributed to the promoting effect of phosphorus on synthesis and translocation rate of photosynthates from leaves to the ear and grains. The simulative effect of P on growth of maize plants might be also due to the fact that phosphorus is a part of molecular structure of nucleic acids DNA and RNA (Mengel and Kirkby, 2001). It could be concluded that, the phosphorus fertilizer had a major effect on the productivity of maize plant, hence increased grain yield and its components. Similar results were also reported byHussain, (1991) andSinha,*et al.* (1995).

Table 2. Effect of the applied treatments on plant height and ear characters of maize plants.

Treatment **P levelsP2O5kg/fed**	**S levels (kg /fed)**	**Plant height (cm)**	**Ear length (cm)**	**Ear diameter (cm)**	**Ear weight (g)**	**Raw number /ear**	**Grain number /raw**
control	Control	1.97	21.00	4.08	168	12.67	36.33
	50 kg S/fed	2.34	23.00	4.42	172	14.00	40.33
	100 kg S/fed	2.45	24.00	4.59	180	14.67	45.67
	150kg S/fed	2.53	25.00	4.61	185	15.33	47.00
	Mean	2.32	23.25	4.43	176	14.17	42.33
15 P_2O_5kg/fed	Control	2.57	23.67	4.58	190	14.00	48.67
	50 kg S/fed	2.59	25.67	4.74	202	15.33	49.00
	100 kg S/fed	2.62	26.00	4.78	211	16.33	51.33
	150kg S/fed	2.69	25.67	4.87	217	16.67	53.00
	Mean	2.62	25.25	4.74	205	15.58	50.50
30 P_2O_5kg/fed	Control	2.73	25.00	4.93	225	15.67	51.33
	50 kg S/fed	2.79	25.67	5.02	231	16.67	52.67
	100 kg S/fed	2.86	26.00	5.18	239	17.00	55.00
	150kg S/fed	2.91	27.00	5.25	257	17.67	56.67
	Mean	2.82	25.92	5.10	238	16.75	53.92
Mean	Control	2.42	23.22	4.53	194	14.11	45.44
	50 kg S/fed	2.57	24.78	4.73	202	15.33	47.33
	100 kg S/fed	2.64	25.33	4.85	210	16.00	50.67
	150kg S/fed	2.71	25.89	4.91	220	16.56	52.22
L.S.D. at 5%	P levels	0.049	1.22	n.s.	4.31	0.23	2.48
	S levels	0.034	1.20	n.s.	2.74	0.62	2.14
	Interaction	0.049	n.s.	n.s.	3.92	n.s.	n.s.

Data in Table (3) showed the effect of tested levels of both P and S fertilizers on grain quality. All the studiedquality characteristics were significantly affected by the application of P- fertilizer. The maximum values were attained from the plots received the highest P rate (30kg P_2O_5/fed). The treatment of P- fertilizer at the rate 30kg P_2O_5/fed achieved the highest 100-grain weight (38.70g), grain yield (4473 kg/fed), protein content (12.96%) and oil content (7.53%) and it was significantly superior to the other P treatments. The role of phosphorus in protein formation is through providing the energy required for the synthesis of protein. Also, the increase in oil content with phosphorus application could be due to the fact that phosphorus helped in synthesis of fatty acids and their etherification by accelerating biochemical reactions in glyoxalate cycle (Dwivedi and Bapat, 1998). These results are in agreement with Nassar*et al.* (2005).

Grain protein and oil contents were also significantly influenced by different levels of sulphur (Table 3). Application of sulphur at the rate of 150kg per fed produced the highest protein and oil contents of maize grain.It might be due to the fact that sulfur is a constituent of amino acids and thus it is vital for protein production.Meanwhile, both grain protein and oil contents were also significantly affected by the interaction between P and S application.The effect of applied P on crop growth depends on level of S in soil and vice versa, as P and S are both absorbed by plants in anionic form from the soil.This positive significant interaction might be owing to the increased uptake of nutrients like N, P, and S with the combined application of P and S, which helped in better nutrition of maize for optimum growth and development.The interaction effect of P and S was significant, thereby indicating a more beneficial effect of the two in combination.Similar finding was also reported by (Havlin*et al.,* 1999) and Kandpal and chandel (1993).The total carbohydrate content, starch content and TSS (Total Soluble Sugars) in maize grain were significantly influenced by the application of different levels of both P and S fertilizers (Table 3). The highest amounts of total carbohydrate (79.55%), starch (76.8%) and TSS (2.75%) were obtained from the P30S150 combination. In this regard Kumar and Singh (1981) studied the effect of sulphur, phosphate and molybdenum on sugar content and reported that these nutrients increased reducing, non-reducing and total sugar contents of soybean leaf.

III: Nutrient contentsin grain

Data in Table (4) and Fig. (6-7) pointed out that application of phosphorus and sulfur fertilization and their combinations increased significantly the nutrient content of N, Pand K in maize grains as compared to the control.Combination of phosphorus and sulfur fertilization had marked influence on nutrient uptake in grains. Application of phosphorus and sulfur fertilization at rate $P_{30}S_{150}$ recorded higher uptake in grains and was significantly superior to control (P_0S_0). This trend might be due toincreased growth and total dry matter production and yield.Application of sulfur to a deficient soil is known to improve the availability of other nutrients which are considered vitally important for the plant.Similar results were obtained by Babhulkar*et al.,* (2000).

Table 3. Effect of the applied treatments on grain yield and its quality

Treatment P levels P2O5 kg/fed	S levels(kg /fed)	Grain yield(kg/fed)	Weight of 100 grain (g)	Protein content %	Carbohydrate %	Starch (%)	TSS (%)	Oil (%)
control	Control	2940	29.84	7.87	60.80	59.20	1.60	4.53
	50 kg S/fed	3267	31.84	9.41	63.25	61.50	1.75	4.77
	100 kg S/fed	3406	32.23	9.85	65.68	63.80	1.88	4.98
	150kg S/fed	3522	33.17	10.26	66.20	64.30	1.90	5.02
	Mean	3284	31.77	9.35	63.98	62.20	1.78	4.83
$15p_2o_5$kg/fed	Control	3693	33.95	10.38	69.55	67.40	2.15	5.44
	50 kg S/fed	4053	35.27	10.83	69.93	67.73	2.20	5.77
	100 kg S/fed	4154	35.53	11.29	70.30	68.20	2.10	6.50
	150kg S/fed	4278	36.46	11.51	70.90	68.68	2.23	6.75
	Mean	4045	35.30	11.00	70.17	68.00	2.17	6.12
$30p_2o_5$kg/fed	Control	4341	37.32	11.97	74.05	71.50	2.55	6.98
	50 kg S/fed	4402	38.08	12.50	74.55	72.20	2.35	7.50
	100 kg S/fed	4494	39.13	13.11	74.80	72.40	2.40	7.69
	150kg S/fed	4653	40.26	14.25	79.55	76.80	2.75	7.95
	Mean	4473	38.70	12.96	75.74	73.23	2.51	7.53
Mean	Control	3658	33.70	10.07	68.13	66.03	2.10	5.65
	50 kg S/fed	3907	35.06	10.91	69.24	67.14	2.10	6.01
	100 kg S/fed	4018	35.63	11.42	70.26	68.13	2.13	6.39
	150kg S/fed	4151	36.63	12.01	72.22	69.93	2.29	6.57
L.S.D. at 5%	P levels	26.12	0.61	0.07	0.21	0.26	0.10	0.06
	S levels	25.32	0.94	0.06	0.21	0.24	0.06	0.05
	Interaction	36.19	1.34	0.07	0.30	0.34	0.09	0.08

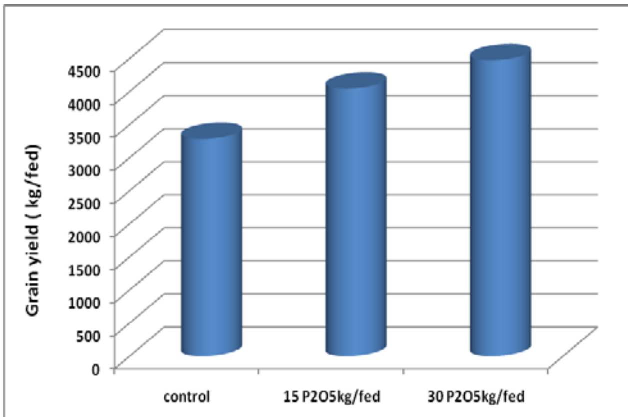
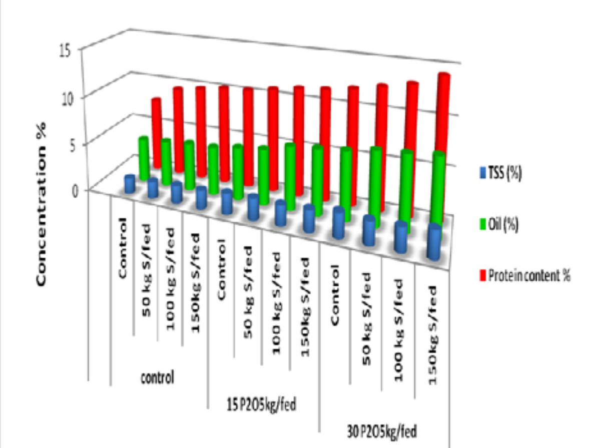


Fig. (1) Effect of phosphorous levels on grain yield



F[g.(3) Effect of the applied treatments on grain quality

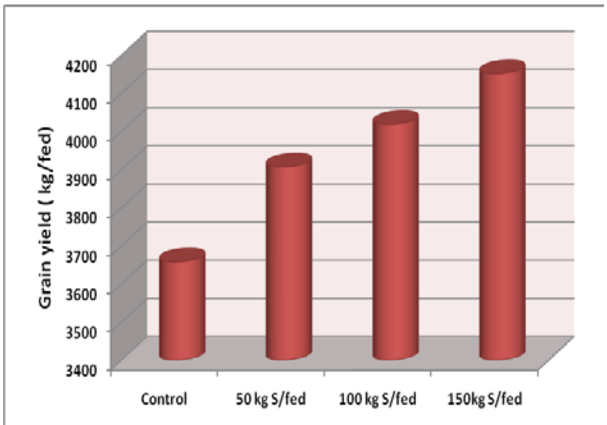


Fig. (2) Effect of Sulfur levels on grain yield

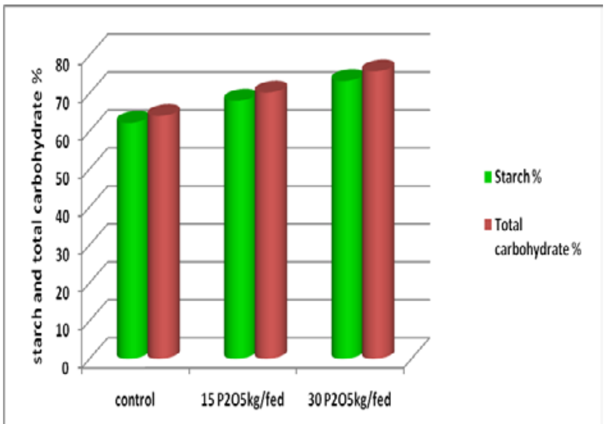


Fig. (4) Effect of phosphorous levels on starch and total carbohydrate

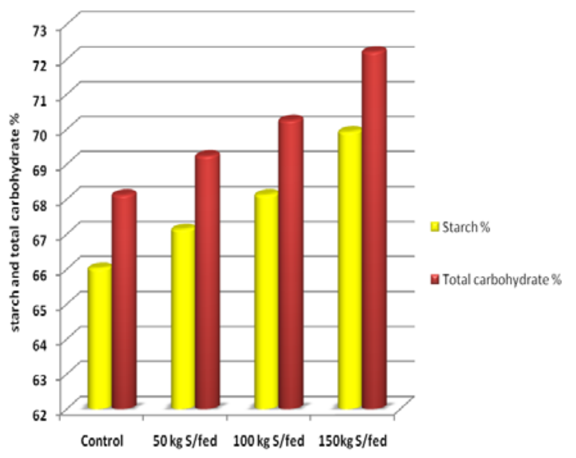


Fig. (5) Effect of Sulfur levels on starch and total carbohydrate

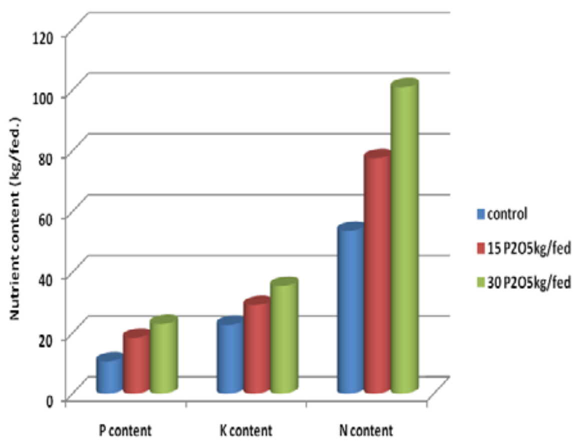


Fig. (6) Effect of phosphorous levels on nutrient content of grain

Von Uexkull, 1986)found that Sulfur availability may influence photosynthetic rate since ferredoxin and acetyl-CoA contain Sand play a significant role in the reduction of CO2 andproduction of organic compounds. Nutrient uptake by crops is mainly a function of crop yield and nutrient concentration in grain and straw. The concentration of nutrients also increases due to S fertilization because of the improved nutritional environment in rhizosphere and consequently in the plant system (Dewal and Pareek 2004).Also, sulfur is necessary for enzymatic reactions, chlorophyll formation, synthesis of certain amino acids and vitamins, hence, it helps to produce a good vegetative growth leading to have a high yield.

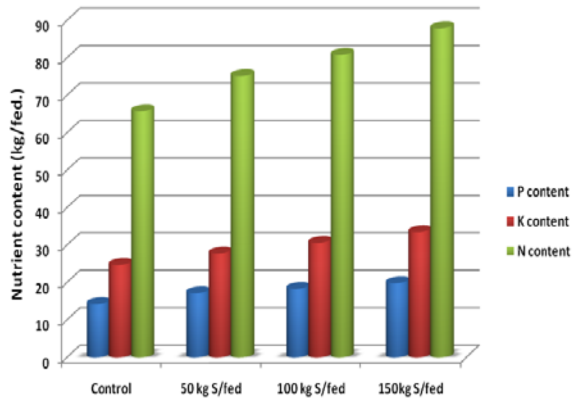


Fig. (7) Effect of Sulfur levels on nutrient content of grain

Table 4: Effect of the applied treatments on nutrient content of grain.

Treatment		**Macronutrients (%)**			**Macronutrients content (kg/fed)**		
P levels P2O5 kg /fed	**S levels(kg /fed)**	**N**	**P**	**K**	**N**	**P**	**K**
control	Control	1.37	0.29	0.63	40.24	8.43	18.62
	50 kg S/fed	1.64	0.32	0.67	53.47	10.45	21.78
	100 kg S/fed	1.71	0.34	0.69	58.35	11.47	23.50
	150kg S/fed	1.78	0.35	0.76	62.84	12.33	26.88
	Mean	1.63	0.32	0.69	53.72	10.67	22.69
15p$_2$o$_5$kg/fed	Control	1.81	0.36	0.64	66.67	13.42	23.76
	50 kg S/fed	1.88	0.47	0.69	76.34	18.91	27.97
	100 kg S/fed	1.96	0.49	0.75	81.56	20.22	31.30
	150kg S/fed	2.00	0.50	0.79	85.63	21.39	33.66
	Mean	1.91	0.45	0.72	77.55	18.48	29.17
30p$_2$o$_5$kg/fed	Control	2.08	0.48	0.73	90.37	20.84	31.69
	50 kg S/fed	2.17	0.50	0.76	95.70	22.16	33.60
	100 kg S/fed	2.28	0.52	0.82	102.46	23.22	37.00
	150kg S/fed	2.48	0.55	0.86	115.31	25.75	39.86
	Mean	2.25	0.51	0.79	100.96	22.99	35.54
Mean	Control	1.75	0.38	0.67	65.76	14.23	24.69
	50 kg S/fed	1.90	0.43	0.71	75.17	17.18	27.78
	100 kg S/fed	1.99	0.45	0.75	80.79	18.30	30.60
	150kg S/fed	2.09	0.47	0.80	87.93	19.82	33.47
L.S.D. at 5%	P levels	0.011	0.033	0.020	0.72	1.42	0.86
	S levels	0.009	0.026	0.025	0.61	1.00	1.02
	Interaction	4.264	3.661	3.586	0.88	1.43	1.45

CONCLUSION

From the aforementioned data, it could be concluded that raising phosphorus rate up to 30kg P_2O_5 /fed induced the greatest increases of maize yields and yield components as well as some grain mineral contents (N,P and K) and grain quality. The application of sulphur raised the mean values of the same parameters. Using phosphorus plus sulphur fertilizers gave a significant promotive effect of yield as well as some grain mineral contents (N, P and K) and grain quality of maize.

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تأثير المستويات المختلفة للفوسفور والكبريت على محصول الذرة الشامية وجودته

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اقيمت تجربتان حقليتان بقرية الشعراوى بمنطقة البستان- النوبارية محافظة البحيرة – مصر خلال الموسمين الصيفيين 2013 و 2014بهدف دراسة تأثير مستويات مختلفة من الفوسفور والكبريت المعدنى على إنتاجية محصول الذرة ومكوناته وجودة الحبوب اشتملت التجربة على اثنتى عشرة معاملة حيث استخدم التصميم الاحصائى للقطع المنشقة فى ثلاث مكررات ، استخدم فيها ثلاثة مستويات من الفوسفور (كنترول- 15-30 كجمفو2ا5 للفدان) وأربعة مستويات من الكبريت (0، 50، 100 و 150 كجم كبريت/فدان) وايضا التفاعل بينهما على المحصول والمحتوى الكيماوي (صفات الجودة) للحبو بصنف (هجين ثلاثى 354) أظهرت هذه الدراسة أن إضافة السماد الفوسفاتى أو الكبريت منفردا أو معا لها تأثيرات معنوية على معظم الصفات المدروسة وكان التأثير أفضل عند إضافتهما معا. وقد ازدادت قيم جميع الصفات تحت الدراسة زيادة معنوية بزيادة معدلات كل من السماد الفوسفاتى والكبريت وأعطت المعاملة 30 كجم فو$_2$أ$_5$ أو 150 كجم كبريت /فدان أعلى القيم لطول النبات (2,82 أو 2,71 م) ، وزن الكوز (238 أو 220 جم/كوز) ، وزن 100 حبة (38,7 أو 36,63 جم) محصول الحبوب (4473 أو 4151 كجم /فدان) ونسبة البروتين فى الحبوب (12,96 أو 12,01 % لكل من السماد الفوسفاتى والكبريت على التوالى) وذلك مقارنة بالمعدلات الاقل لكل منهما .وأظهرت النتائج أن إضافة السماد الفوسفاتى والكبريت معا قد حقق أعلى القيم وتفوقت المعادلة السمادية (30 كجمفو 2أ5 + 150 كجم S /فدان) المخاليط الاخرى موضحا أن هذه المعادلة مناسبة للحصول على أعلى محصول ذرة ذو صفات جودة أفضل تحت هذه الظروف