J. Agric. Sci. Mansoura Univ., 32 (11): 9741 - 9754, 2007

BENEFICIAL EFFECTS OF PHOSPHOGYPSUM COMBINED WITH N-FERTILIZERS AND ORGANIC MANURE ON CORN YIELD AND N - P AVAILABILITY IN SOIL

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ABSTRACT

Two successive field experiments were carried out in Sakha Agric. Res. Stat., using maize (*Zea maize* L.) var. third hybrid 323. The experiment design was split-split plot. Nitrogen sources were added to the main plots as urea (U) and ammonium sulfate (AS) fertilizers at a rate of 90 kg N fed^{-1}. Organic manure was added to the sub-sub-plots at 3 levels (0, 4 and 8 MG fed^{-1}). Phosphogypsum was added at 4 levels (0, 3, 6 and 9 Mg fed^{-1}). All the treatments were replicated four times. The N fertilizers, OM and PG were added in two equal doses.

Mean value of grain yield with U fertilizer was slightly higher (3.89 Mg fed^{-1}) than with AS fertilizer (3.54 Mg fed^{-1}) in 1998 season. A significant increase was obtained in grain yield due to PG application. In 1998 season, Δ increase % was 8.1, 11.3 and 17.3% with PG_1, PG_2 and PG_3, respectively. The corresponding values in 1999 were 2.4, 7.5 and 13.7%. However, OM treatments led to slight decrease in grain yield with the two seasons.

Combination of PG and OM had improved corn grain yield in both seasons with U or AS and enhanced OM efficiency. The highest grain yield was obtained with N + OM_1 + PG_3 treatment (4.55 MG fed^{-1}) in 1998 with U fertilizer. The interaction of U, PG and OM significantly increased 100-grain weight of corn as compared with control treatment (N alone) in 1999 seasons, but not, in 1998 season.

The combination of PG and OM treatments in the two seasons with both U and AS fertilizers led to a significant increase in N content of corn grains as compared with control treatment (N alone). Addition of PG_1, PG_2 and PG_3 increased P content to 8.81, 11.52 and 12.31 kg P fed^{-1}, respectively, as compared with the control treatment (7.57 kg P fed^{-1}) with U fertilizer in 1998. When OM was increased, P content in grains increased with U or AS fertilizers in both seasons.

All PG and OM treatments, in the two seasons with U or AS fertilizer led to a significant increase in available P and N as compared with the control treatment (N alone).

INTRODUCTION

Agriculture production is generally dependent on N fertilizers. Thus available N loss from agriculture systems is expensive waste of the resources and environmentally increasing NO^-_3 in the environment. Phosphogypsum (PG),is a by-product of phosphoric acid fertilizer inexpensive, strongly acidic materials (pH = 2.5) and have a high calcium, iron and manganese content. So it is postulated that PG might be used to lower soil pH and provides Ca, Fe, and Mn (Bayrakli, 1990). Also, PG is used as a soil amendment to improve soil structure and water penetration and to reduce the amount of runoff and erosion by 50 and 60%, respectively (Warrington *et al.*, 1989). A positive yield response to PG in field and green house studies were found for several crops, including corn, potatoes, cantaloupes and watermelons (Hunder, 1996). Abou-Youssef (2001) showed that, PG application on loamy soil increased pepper fruits yield with increasing PG rate up to 906 kg/fed and total S uptake by plants was greater at PG rate of 9.6 kg/plot. Isableo and Rechcigl (1993) reported that PG appears to be as good as, if not better than, mined gypsum as a source of S and Ca for crops. Jack (1997) showed that PG is a potential low cost source of S and Ca for forages. Therefore, an insight view is needed to evaluate the use of phosphogypsum in the Egyptian soils and its impact on nutrition status of soil.

The main target of this study was to evaluate the influence of applied phosphogypsum (PG) and organic manure (OM) to soil in combination with urea (U) or ammonium sulfate (AS) on corn yield components, mineral contents and availability of N and P in soil under field experiment.

MATERIALS AND METHODS

Two field experiments were carried out at Sakha Agriculture Research Station Farm, Kafr El-Sheikh Governorate, Northern Delta, Egypt during two successive seasons 1998 and 1999. Some soil characteristics are presented in Table (1).

Table (1):Some chemical and physical soil characteristic of the soils used in field experiments.

Soil properties	1998	1999
pH (1: 2.5) soil: water ratio	8.03	8.06
ECe (dSm^{-1} at 25°C)	2.11	1.83
S.P (saturation percentage)	75.8	76.5
OM%	1.72	1.66
C.E.C. (cation exchange cap) $Cmol_c\ kg^{-1}$	40.46	37.88
Available N and P ($mg\ kg^{-1}$)		
N (KCl 1.0 N extract)	31.5	33
P ($NaHCO_3$-extractable P).	8	9
DTPA-extracted Fe, Zn and Cu ($mg\ kg^{-1}$)		
Fe	8.86	8.6
Zn	1.43	2.2
Cu	5.84	4.7
Water soluble ions, (mmole/L)*		
Ca^{++}	0.9	1.00
Mg^{++}	0.8	1.1
Na^{+}	2.7	2.3
K^{+}	0.18	0.19
$CO_3^{=}$	n.d	n.d
HCO_3^{-}	3.00	2.5
Cl^{-}	2.50	2.0
$SO_4^{=}$	0.14	1.1
Particle size distribution:		
Clay %	58.1	56.2
Silt %	30.3	30.5
Sand %	11.7	13.5
Texture	Clayey	Clayey
$CaCO_3$ (%)	4.22	4.20

*** Measured in 1: 5 soil water extract**
kln.d. = not detected

Maize grains (*Zea mays* L.), variety third-hybrid 323 was used. Sheep manure was used as OM (total N = 0.7%, pH = 7.48 in 1: 2.5 suspension C/N ratio= 22%). Phosphogypsum (PG) is a by-product of phosphoric acid manufacture at Abu-Zaable. Some chemical composition of PG are: P_2O_2 = 0.7-1.0%, SiO_2 = 11.68%, CaO = 31.5%, SO_4 = 55.1%, NaO = 0.2%, Zn = 2.66 mg/kg, Mn = 16.22 mg/kg, Cu = 0.28 mg/kg, Ni = 0.66 mg/kg, Pb = 1.74 mg/kg, pH in 1: 2.5 soil: water = 2.94 and EC in 1: 2.5extract = 4.2 dS/m (El-Saady, 2002).

Nitrogen fertilizer was applied as urea (U, 46% N) or ammonium sulphate (AS, 20.5% N) a dose of 90 kg N fed^{-1}. This N dose was applied at two equal a parts; the first part was applied after 20 days from planting (before the first irrigation) and the second part was added before the second irrigation.

Treatments of organic manure were 0, 4 and 8 Mg fed^{-1}. Each rate was splited into two equal doses.

Four treatments of phosphogypsum were used as follows: 0, 3, 6 and 9 Mg fed^{-1}. Each rate was splited into two equal doses.

Nitrogen fertilizers, organic manure and phosphogypsum, at their given levels, were thoroughly mixed to be ready for application in the various treatments as follows:

1. U.
2. U + PG_1
3. U + PG_2
4. U + PG_3
5. U + OM_1
6. U + PG_1 + $O.M_1$
7. U + PG_2 + $O.M_1$.
8. U + PG_3 + $O.M_1$.
9. U + $O.M_2$.
10. U + PG_1 + $O.M_2$.
11. U + PG_2 + $O.M_2$.
12. U + PG_3 + $O.M_2$.
13. AS.
14. AS + PG_1
15. AS + PG_2
16. AS + PG_3.
17. AS + OM_1
18. AS + PG_1 + OM_1.
19. AS + PG_2 + $O.M_1$
20. AS +PG_3 + OM_1
21. AS + OM_2
22. AS + PG_1 + OM_2
23. AS + PG_2 + OM_2
24. AS + PG_3 + OM_2

Where:

PG_1 = 7.5 kg/plot equivalent 3 ton/fed.
PG_2 = 15 kg/plot equivalent 6 tone/fed.
PG_3 = 22.5 kg/plot equivalent 9 ton/fed.
$O.M_1$ = 10 kg/plot equivalent 4 ton/fed.
$O.M_2$ = 20 kg/plot equivalent 8 ton/fed.

The plot area was 10.5 m^2. The grains of maize were sown on 23 May, 1998 and 28 May 1999. to represent 40 plants/plot, (2000 plants/fed.). Combinations of fertilizers, organic manure and phosphogypsum were added as band application in two equal doses. The first and second doses were applied after thinning of plants that preceded 1^{st} and 2^{nd} irrigation. The potassium fertilizer and the agriculture practices commonly used in the Research Station were carried out. No phosphorus fertilizer was applied in this study. Soil samples were collected during the growth period for the chemical analysis (available N and P). Plant samples (three ear leaves at silking stage, 70-75 days after planting) were also collected for analysis (Chapman and Pratt, 1961).

The two successive field experiments were conduced in split-split plots design with four replicates. The main plots were randomly assigned to the nitrogen treatment and the sub plots, were randomly assigned to the three organic manure levels. While, the sub-sub-plots were randomly assigned to the four phosphogypsum levels.

Yield and yield components:

- 100 grains weight was counted and their weights were measured.
- Grain yield: Grains of each plot were collected and their weights were measured (Mg fed^{-1}).

Soil analysis:

- Organic matter of the soil was determined using the wet digestion method, Walkley and Black's (Jackson, 1958).
- Soil pH was measured in 1: 2.5 soil: water suspension according to Page *et al.* (1982).
- Mechanical analysis was determined by the Pipette method: (Piper, 1950).
- Electrical conductivity (EC) was measured in the soil paste extract using conductivity meter according to Jackson (1958).
- Water soluble ions Soil was extracted 1: 5 soil: water extraction to determine soluble cations and anions (Na^+, Mg^2, K^+, Ca^{2+}, CO^{2-}_3, HCO^-_3, Cl^- and SO^{2-}_4) as described by Page (1982).
- Available nitrogen was extracted by using 1.0 M KCl according to Cottenie *et al.* (1982) and determined by micro Kjeldahl apparatus.
- Cation exchange capacity (CEC) was determined according to Page (1982).
- Available-P was extracted with 0.5 M $NaHCO_3$ solution at pH 8.5 according to Olsen *et al.* (1954) and determined specrophotometrically by ascorbic acid method (Murphy and Riley, 1962). Total calcium carbonate was determined volumetrically using Collins calcimeter and calculated as total $CaCO_3$ percent, according to Richards (1954).

Plant analysis:

The collected plants the first washed by tap water then by distilled water, dried in an oven at 65°C for 48 hrs, ground in skinless mill. The over dried plant material was wet digested wth $HClO_4$ and H_2SO_4 according to Chapman and Pratt (1961).

Nitrogen and phosphors were determined in the digested solution and expressed percentage. Nutrients uptake were calculated by multiplying their concentrations by grain yield on dry matter basis.

Nitrogen was determined using Kjeldahl method as described by Page (1982). Phosphorus, was determined colorimetrically, using the hydroquinone method as described by Snell and Snell (1967).

RESULTS AND DISCUSSION

Grains yield:

Table 2 showed that the mean values of grains yield of maize plants fertilized with urea were slightly higher (3.89 Mg fed^{-1}) as compared with those fertilized with AS (3.54 Mg fed^{-1}) in 1998 season. However, this increase was not significant. There was also no difference between U and AS in the second season (1999). Similar results were obtained by El-Baisary *et* *al.* (1980) they reported that increasing nitrogen supply improved maize yield and N uptake, but N sources had no significant differences.

Statistical calculations showed a significant increase in grain yield due to PG application. For instance, the mean grains yield in 1998 season was 3.35 Mg fed^{-1} with the check treatment (no PG was added), which increased to 3.62, 3.73 and 3.93 Mg fed^{-1} when PG was added at PG_1, PG_2 and PG_3 levels, respectively. The corresponding values in 1999 season were 3.35 Mg fed^{-1} (check treatment) and 3.43, 3.60 and 3.81 Mg fed^{-1}, respectively. Extra increase of grain yield over the control may be expressed by Δ increase % to evaluate the relative influence of added PG. In 1998 season, Δ increase % was 8.1, 11.3 and 17.3 with PG_1, PG_2 and PG_3, respectively. The corresponding values in 1999 were 2.4, 7.5 and 13.7%. It was observed that the mean grains yield as well as the increase in 1999 was less than that of 1998 season. These results agree with those obtained by El-Saady (2002), who reported that increasing PG rates caused a gradual reduction in NH_3-volatilization, thereby more nitrogen derived from fertilizer was saved in the soil system reflecting on the relative increase of grains yield. Moreover, PG material provides phosphorus and some trace elements in available form which may enhance growth and grains yield of corn. Such results are confirmed by the work of Hunter (1989) who reported that, PG would be more effective for increasing plant yield when it is mixed with other fertilizer materials such as urea. It is clear from Table 2 that growth rates were 17-72% less than in the soil with PG. Field tests were made using various rates and placements of PG in conjunction with optimum amounts of other elements as determined by the greenhouse tests. Yield increases attributed to PG ranged from 6% from tomatoes to 107% for corn yield (Hunter, 1989).

Regarding to the effect of added OM treatments on corn grains yield (Table 2), the data showed slight decrease in grains yield of 1998 season and moderate decrease in 1999 season. Mean of grains yield decreases from 3.35 Mg fed^{-1} (N treatment) to 3.34 and 3.26 Mg fed^{-1} after OM had been applied in 1998 season with OM_1 and OM_2, respectively. Expressing such decreases on the form of Δ increase, values were -0.3 and -2.7%. Similar trend was exhibited in 1999 season but with further reduction in grains yield. Values of Δ increase were -7.5 and -18.5% with OM_1 and OM_2, respectively. This could be attributed to that application of OM to the soil increased NH_3-volatilization and therefore, may reduce the amount of readily available N causing reduction of corn grains yield in both seasons. Generally, it was suggested that both NH_3-volatilization and N-immobilization processes had reduced available N and caused N stress. In these circumstances, additional N fertilizer is required to enhance biological decomposition and minimize plant N stress. Similar findings were reported by Mamo *et al.* (1999), who found that compost treatment without N fertilizer resulted in lower grains yield compared with one time application and the opposite effect was found with another compost. They added that C/N ratio of the composts plays a great role and may cause the contradiction that would appear. Beyrouty *et al.* (1988) found that hydrolysis rate was found to be greater when urea was applied directly to corn residue than to soil. In both field trials, urea hydrolysis was more than 2 times faster when urea was added to a residue.

Table (2):Effect of nitrogen sources phosphogypsum (PG) and organic sheep manure (OM) on corn grains yield (Mg fed^{-1}).

Treatments	1998				1999			
	U	AS	Mean	Δ%	U	AS	Mean	Δ%
N	3.29	3.41	3.35	-	3.30	3.4	3.35	-
N + PG_1	3.67	3.57	3.62	8.1	3.48	3.37	3.43	2.4
N + PG_2	3.84	3.61	3.73	11.3	3.78	3.42	3.60	7.5
N + PG_3	3.97	3.89	3.93	17.3	4.21	3.40	3.81	13.7
N + OM_1	3.38	3.31	3.34	-0.3	2.68	3.50	3.10	-7.5
N + OM_1 + PG_1	3.67	3.53	3.60	7.5	3.34	3.76	3.55	6.0
N + OM + PG_2	4.12	3.89	4.01	19.7	3.52	3.83	3.68	9.9
N + OM_1 + PG_3	4.55	4.06	4.31	27.7	3.72	3.86	3.79	13.1
N + OM_2	4.42	3.09	3.26	2.7	2.60	2.85	3.73	-18.5
N + OM_2 + PG_1	3.85	3.42	3.64	8.7	3.78	3.40	3.59	7.2
N + OM_2 + PG_2	3.91	3.35	3.63	8.4	3.93	3.80	3.87	15.5
N + OM_2 + PG_3	3.99	3.39	3.69	10.0	3.90	3.96	3.93	17.3
Mean	3.89	3.54	-	-	3.52	3.55	-	-
LSD N 0.05	NS				NS			
OM 0.05	NS				NS			
PG 0.05	0.45				0.51			
N x OM x PG	NS				NS			

NS = Not significant
PG_1, PG_2 and PG_3 = 3, 6 and 9 MG fed^{-1} of phosphogypsum, respectively.
OM_1 = 4 MG fed^{-1}, OM_2 = 8 Mg fed^{-1}, N = 90 kg N fed^{-1}, AS = ammonium sulphate, U = Urea

Opposing to the effect of OM added to N-fertilizers on reducing grains yield, application of PG at three rates named PG_1, PG_2 and PG_3 had improved corn grains yield in both seasons with varied extent when combined with the two levels of OM_1 (4 Mg fed^{-1}) and OM_2 (8 Mg fed^{-1}). Mean of corn grains yield increased from 3.35 Mg fed^{-1} (N fertilizer alone) to 3.60, 4.01 and 4.31 Mg fed^{-1} with OM_1 plus PG_1, PG_2 and PG_3 combined with N source, in 1998 season, respectively. The corresponding mean values of Δ increase were 7.5, 19.7 and 27.7%. Similar trend was obtained in 1999 season but with slight increase over the control, (9.9, 13.1 and 13.1%). It seems that the superior treatment that produced the highest grains yield as well as Δ increase was N + OM_1 + PG_3 treatment (4.55 Mg fed^{-1}) in 1998 season with urea fertilizer and 4.06 Mg fed^{-1} with (AS) fertilizer.

The beneficial effect of N fertilizer that mixed with PG at varied rates and OM have been reported by El-Saady (2002) who obtained in lab. experiment that a consistent amount of available N was maintained and saved by using this treatment. Therefore, the practice of this combination in field experiment may result in consistent and adequate N supply and cause grain yield to increase.

The set of treatments that contain OM_2 plus PG rates did not much vary as compared with OM_1 treatments. It is also clear that values of Δ increase showed slight difference in the two seasons (Table 2).

100-grain weight:

Table 3 showed a significant increase in 100-grain weight of corn grains in plant grown in 1999 season only due to the treatments as compared to the control treatment (N alone). However, in 1998 season, there were only marked but not significant increases in 100 grain weights. This was a general trend with all PG and OM treatments in the two seasons with either U or AS fertilizers. For example, as PG rates increased, 100-grain weight showed gradual increase in case of U treatments since, values increased from 38.8 gm with U treatment alone to 39.0, 39.23 and 44.37 with PG_1, PG_2 and PG_3 in 1998 season, respectively. Similar trend was obtained with U in 1999 season. On the other hand 100 grain weight increased with PG_1 only in both seasons with AS fertilizer and then decreased with increasing PG.

When OM_1 was added with U, values of 100-grain weight increased from 38.0 gm to 44.37 gm in 1998 season. Also, 100-grain weight showed gradual increase due to PG increase combined with OM_1. Such increase was high when compared with the treatment of U and PG alone (39.0 gm). This indicates that OM_1 had a beneficial effect on 100-grain weight. Similar results were obtained with U, PG and OM_1 in 1999 season when compared with N + PG_1 treatment (38.07 gm). Using OM_2 level, 100-grain weight recorded lower values, in 1998 season (36.6 gm) then it increased upon further addition of PG. It seems that OM_1 combined with PG produced the superior 100-grain weight with combinations of N as AS with PG and O.M showed that value of 100 grain weights were not much varied in the two seasons.

Table (3): Effect of N-sources, phosphogypsum (PG) and organic sheep manure (OM) on 100 grains weight.

Treatments	100 grains weight (gm)			
	1998		1999	
	U	AS	U	AS
N	38.80	42.63	37.93	40.05
N + PG_1	39.00	43.60	38.07	43.91
N + PG_2	39.23	36.47	38.76	41.33
N + PG_3	44.37	39.67	44.68	39.73
N + OM_1	44.37	42.70	38.58	40.33
N + OM_1 + PG_1	44.90	40.80	38.42	43.62
N + OM + PG_2	44.73	38.10	38.24	43.07
N + OM_1 + PG_3	41.00	40.70	41.61	41.45
N + OM_2	36.60	43.00	36.63	37.01
N +,OM_2 + PG_1	39.70	41.03	43.30	37.50
N + OM_2 + PG_2	37.30	44.60	43.09	32.75
N + OM_2 + PG_3	37.70	37.40	43.66	43.52
L.S.D. 0.05				
N	NS		NS	
OM	NS		NS	
PG	NS		5.05	
N x OM x PG	NS		10.52	

NS = Not significant

PG_1, PG_2 and PG_3 = 3.6 and 9 MG fed^{-1} of phosphogypsum, respectively.

OM_1 = 4 Mg fed^{-1}, OM_2 = 8 Mg fed^{-1}, N = 90 kg N fed^{-1}, AS = Ammonium sulphate, U = urea

The statistical analysis revealed that the interactions between nitrogen, OM and PG rates were not significant in 1998 season, but were significant in 1999 season. These results are in agreement with those obtained by Saied (1997) who found that increasing N-fertilizer levels caused significant increase in weights of 100 grain.

Nitrogen content of grains:

Table (4) show a significant increase in N content of corn grains with increasing PG and OM as compared with the control treatment (N alone). This was a general trend with all PG and OM treatments, in the two seasons with either U or AS fertilizers. Increased values were attributed to the combination of PG and OM treatments. For example, as PG rates increased, nitrogen content showed gradual increase in corn grains. In case of U treatments, values increased from 38.49 kg N fed^{-1}, with N treatment alone, to 48.38, 50.3 and 51.04 kg N fed^{-1}, with PG_1, PG_2 and PG_3 in 1998 season, respectively. Similar trend was obtained with AS treatments in both 1998 and 1999 seasons, but the magnitude of values were high in 1999 season than in 1998 season.

When OM was added with N fertilizers, the values of N content in the grains were higher than N treatment alone and slightly less than N + PG treatment values. As OM_1 level was added to N + PG levels, N content increased when PG level increased with comparable high values. These treatments recorded the high amount of N content in corn grains when compared with rest of treatments. Such trend was contained with OM_2 and N + PG treatments with either U or AS fertilizer, in both seasons. In general, these findings are confirmed with those of lab. experiment which showed a beneficial effect on available N due to PG and OM application to the soil (El-Saady, 2002).

Phosphorus content of grains:

This field experiment was carried out without addition of phosphate fertilizer to all treatments, because phosphogypsum contains P in considerable amounts in the form of orthophosphoric acid. Analytical data of PG showed that the percentage of P_2O_5 ranged between 0.7-1.0% and with assuming the mean value of 0.85%, P content of PG_1 treatment (3 MG fed^{-1}) would equal 25.5 kg P_2O_5. The corresponding values of P_2O_5 with PG_2 and PG_3 are 51.0 and 76.5 kg, respectively. This means that PG has easily and readily P form that maintain a considerable amount of P to meet corn requirements and gave promising grain yield as well as grain P content, therefore no need to P fertilizer application.

As shown in Table (4) addition of PG at different rates increased P content in grains when compared with the treatment that received N fertilizers only and no PG. This trend was obtained with all PG and OM treatments, but the extent of increases was much depended on both PG as well as OM rates. When OM was increased, P content in grains increased with the two N fertilizers and in both seasons (1998 ad 1999). Addition of PG_1, PG_2 and PG_3 increased P content to 8.81, 11.51 and 12.31 kg P fed^{-1}, respectively, as compared with the control treatment (7.57 kg P fed^{-1}) with U fertilizer in 1998. The values of P contents in 1999 season, as well as values of AS fertilizer were similar to those of U. It can be concluded, from economical point of view, that PG_3 alone or plus OM_1 when added with N fertilizers would be considered the most promising treatments. It is clear therefore, that PG due to its enrichment with P and some trace elements had been proved its value as inexpensive amendment that create conditions in soil system making nutrition status more available to plant.

Table (4): Effect of N-sources, phosphogypsum (PG) and organic sheep manure (OM) on N and P contents of corn grains (Kg fed $^{-1}$).

Treatments	N content (kg/fed.)				P content (kg/fed.)			
	1998		1999		1998		1999	
	U	AS	U	AS	U	AS	U	AS
N	38.49	41.26	38.61	42.84	7.57	7.50	8.91	8.86
N + PG_1	48.38	42.46	42.11	49.30	8.81	9.10	10.09	9.5
N + PG_2	50.30	43.68	49.52	54.46	11.52	9.75	10.96	11.29
N + PG_3	51.04	45.51	49.68	57.95	12.31	13.23	14.74	11.40
N + OM_1	49.98	43.36	39.27	49.00	8.21	8.28	6.16	7.7
N + OM_1 + PG_1	51.38	47.42	41.08	50.76	10.64	10.94	10.75	8.53
N + OM + PG_2	61.39	47.07	41.18	54.07	11.95	10.89	11.38	10.19
N + OM_1 + PG_3	63.70	49.50	55.463	57.43	13.65	11.77	13.90	10.88
N + OM_2	43.09	38.93	41.34	43.89	10.26	9.89	8.32	8.84
N + OM_2 + PG_1	49.44	44.80	48.01	49.30	11.17	9.58	9.83	9.18
N + OM_2 + PG_2	50.27	44.58	56.56	58.52	12.12	10.05	12.58	9.11
N + OM_2 + PG_3	50.27	18.41	58.55	59.00	12.37	10.51	12.09	9.88
L.S.D. 0.05 N x OM x PG	1.69		2.26		2.02		1.49	

PG_1, PG_2 and PG_3 = 3, 6 and 9 Mg fed^{-1} of phosphogypsum, respectively.
OM_1 = 4 MG fed^{-1}, OM_2 = 8 Mg fed^{-1}, N = 90 kg N fed^{-1}, AS = Ammonium sulphate, U = Urea.

Nitrogen percent of ear leaf:

Table (5) showed that PG significantly increased N percentage in corn ear leaf when U was used in both seasons compared with the control (U alone). The values increased from 1.26% with urea treatment alone to 2.52, 2.10 and 2.10% with PG_1, PG_2 and PG_3 in 1998 season, respectively. The corresponding values in 1999 season were 1.33% with U treatment and 1.6, 2.17 and 1.61% with PG treatments. Such trend was found with OM_1 and PG rates in the two seasons. Combining OM_2 with PG rates had no effect on N percentage in ear leaf in 1998 season but not in 1999 season.

AS fertilizer showed opposing effect on N percentage, since both PG rates and organic manure levels had decreased N% in ear leaf in the two seasons. The results also showed marked variations with U and AS fertilizers.

Phosphorus percent of ear leaf:

Table (5) showed a significant increase in phosphorus percent of corn ear leaf with all treatments as compared with the control treatment (N alone). This was a general trend with all PG treatments in the two seasons with both U and AS fertilizers. For example: as PG rates increased, P percentage showed gradual increase in ear leaf. In case of U treatments, the values increased from 0.26%, with N treatment alone, to 0.30, 0.30 and 0.32% with PG_1, PG_2 and PG_3, respectively in 1998 season. Similar trend was obtained with U treatments in 1999 season, and also with AS treatments in both seasons. However, the magnitudes of these values were higher in 1999 season than in 1989 season.

No differences were detected in P percentage of corn ear leaf due to OM with either U or AS fertilizers in the both seasons. When OM levels were added to N + PG levels, P percentage increased as PG role increased in both seasons, but the magnitude of values were high in 1999 season especially with OM_2 treatments. For example, in case of U treatments, the values increased from 0.26% with N + OM treatment alone to 0.28, 0.30 and 0.31% with PG_1, PG_2 and PG_3 in 1998 season, respectively. Similar trend was obtained with AS treatments in both seasons.

Maximum mean value was obtained with (N + OM_2 + PG_3) treatment and the lower mean value was with control (N alone). In general, these findings are expected due to PG materials enriched with P_2O_5, that led to increase available P and more uptake by corn plant.

Table (5): Effect of N-sources phosphogypsum (PG) and organic sheep manure (OM) on N and P percent of corn ear leaf.

Treatments	N %				P %			
	1998		1999		1998		1999	
	U	AS	U	AS	U	AS	U	AS
N	1.26	2.24	1.33	2.17	0.26	0.26	0.26	0.27
N + PG_1	2.52	1.54	1.61	2.17	0.30	0.28	0.30	0.29
N + PG_2	2.10	2.10	2.17	1.47	0.30	0.31	0.30	0.32
N + PG_3	2.10	2.02	1.61	2.03	0.32	0.32	0.36	0.33
N + OM_1	1.68	2.38	1.61	1.75	0.26	0.25	0.26	0.28
N + OM_1 + PG_1	1.96	1.40	1.75	1.19	0.27	0.28	0.32	0.27
N + OM + PG_2	2.38	1.78	1.89	1.47	0.28	0.30	0.30	0.34
N + OM_1 + PG_3	2.66	1.40	2.45	1.47	0.30	0.31	0.32	0.39
N + OM_2	1.40	2.10	1.33	1.75	0.26	0.22	0.30	0.23
N + OM_2 + PG_1	1.26	1.26	1.89	1.47	0.28	0.26	0.30	0.27
N + OM_2 + PG_2	1.26	1.40	1.90	1.75	0.30	0.28	0.36	0.33
N + OM_2 + PG_3	1.20	1.96	2.17	1.47	0.31	0.31	0.40	0.38
LSD 0.05 N x OM x PG	0.11		0.16		0.02		0.02	

PG_1, PG_2 and PG_3 = 3, 6 and 9 Mg fed^{-1} of phosphogypsum, respectively.
OM_1 = 4 Mg fed^{-1}, OM_2 = 8 Mg fed^{-1}, N = 90 kg N fed^{-1}, AS = Ammonium sulphate, U = Urea

Available nitrogen in the soil:

Table (6) showed significant increases in the amounts of available N with PG and OM treatments as compared with the control (N alone). This was a general trend with all PG and OM treatments, in the two seasons with either U or AS fertilizers. Increased values are related to the interaction of N, PG and OM treatments. For example: as PG rates increased, the amounts of available N showed gradual increase in the soil. In case of U treatments, the values increased from 22.4 µg/gm, with U treatment alone to 28, 33.6 and 50.4 µg/gm with PG_1, PG_2 and PG_3, respectively in 1998 season. Similar trend was obtained with AS treatments in the both seasons.

When OM was added with N fertilizers, the amount of available N was intermediate between the values of N alone and N + PG treatments. While OM_2 decreased available-N. This may be due to N-immobilization with OM_2. However, OM_1 level with U or AS + PG, available N increased, especially with PG_3 level. Such trend was continued with OM_2 and N + PG treatments with either U or AS fertilizers, in both seasons. These finding may be due to a beneficial effect of PG and OM on available nitrogen in the soil. These data are in agreement with the results obtained from laboratory studies where PG reduced N-loss as NH_3-volatilization. Thereby, more nitrogen derived from fertilizer was saved in the soil system reflecting the increase of available nitrogen in the soil.

6.Available phosphorus in the soil:

Table (6) showed a significant increase in available P due to PG_2 and PG_3 treatments as compared with the control treatment (N alone). This was a general trend with PG and OM treatments, in the two seasons with both U and AS fertilizers. The interaction between N sources, PG, and OM treatments led to highly significant increase of available P in the soil. For example, as PG rates increased, available P showed gradual increase in the soil. In case of U treatments, values increased from 14.52 µg/gm with U treatment alone to 16.13 and 18.55 µg/gm with PG_2 and PG_3 in 1998 season, respectively. Similar trend was obtained with AS treatments in both seasons, but the magnitude of values were higher in 1999 seasons than in 1998 season.

Table (6): Available N and P in soil treated with N sources, phosphogypsum (PG), and organic sheep manure (OM).

Treatments	N µg/gm				P µg/gm			
	1998		1999		1998		1999	
	U	AS	U	AS	U	AS	U	AS
N	22.4	28.0	26.8	33.6	14.52	12.90	19.36	17.74
N + PG_1	28.0	28.0	26.8	39.2	14.52	16.13	21.78	20.16
N + PG_2	33.6	33.6	33.6	39.2	16.13	16.94	22.58	19.36
N + PG_3	50.4	39.2	37.2	44.8	18.55	25.81	24.20	22.58
N + OM_1	28.0	33.6	26.8	28.0	16.13	14.52	21.78	21.78
N + OM_1 + PG_1	33.6	44.8	28.0	33.6	16.16	16.13	21.78	24.20
N + OM_1 + PG_2	33.6	39.2	33.6	39.2	17.74	16.13	24.20	25.81
N + OM_1 + PG_3	39.2	50.4	44.8	44.8	22.58	17.74	32.10	22.58
N + OM_2	22.4	22.4	28.0	33.6	13.71	14.52	22.58	19.36
N + OM_2 + PG_1	22.4	44.8	33.6	33.6	14.52	14.52	20.97	20.16
N + OM_2 + PG_2	44.8	50.4	33.6	39.2	17.74	18.55	22.58	20.97
N + OM_2 + PG_3	50.4	50.4	44.8	39.2	19.36	20.97	24.20	28.23
LSD 0.05 N x OM x PG	3.35		3.42		2.79		3.84	

PG_1, PG_2 and PG_3 = 3, 6 and 9 Mg fed^{-1} of phosphogypsum, respectively.
OM_1 = 4 Mg fed^{-1}, OM_2 = 8 Mg fed^{-1}, N = 90 kg N fed^{-1}, AS = Ammonium sulphate, U = urea

When OM was added with N fertilizer the values of available P were intermediate between N treatment alone and N + PG treatment values. As PG was increased the amounts of available P increased with comparable high values. For example, in case of U treatments, values increased from

التأثير المحسن للفوسفوجبسم والتسميد النتروجينى والعضوى على محصول الذرة وبسر النتروجين والفوسفور

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أجريت تجربتان حقليتان فى محطة بحوث سخا الزراعية على نبات الذرة (هجين ثلاثى ٣٢٣). التصميم الإحصائى ــ القطع تحت المنشقة. خصصت القطعة الرئيسية للأسمدة النيتروجينية ــ اليوريا وكبريتات الأمونيوم بمعدل ٩٠كجم نيتروجين للفدان. أضيف السماد العضوى للقطع المنشقة فى ثلاث مستويات (صفر ، ٤ ، ٨ ميجا جرام/فدان). وأضيف الفوسفوجيبسيم للقطع تحت المنشقة فى أربع مستويات (صفر ، ٣ ، ٦ ، ٩ ميجاجرام/فدان). عدد المكررات فى التجربة أربعة. اضيف الأسمدة النيتروجينية ، السماد العضوى ، الفوسفوجيبسيم فى جرعتين متساويتان.

أوضحت النتائج أن متوسط محصول حبوب الذرة فى موسم ١٩٩٨ مع استخدام اليوريا ــ كان أكثر قليلا (٣,٨٩ ميجاجرام/فدان) عنه فى حالة سماد كبريتات الأمونيوم (٣,٥٤ ميجاجرام/فدان). كما تشير النتائج للزيادة الجوهرية فى محصول الذرة نتيجة استخدام الفوسفوجيبسيم. كان مقدار الزيادة (Δ increase) فى موسم ١٩٩٨ معبرا عنه كنسبة مئوية ٨,١ ، ١١,٣ ، ١٧,٣ وذلك للمستويات الثلاث ٣ ، ٦ ، ٩ ميجا جرام من الفوسفوجيبسيم. الزيادة المقابلة فى محصول الحبوب فى ١٩٩٩-٢,٤ ، ٧,٥ ، ١٢,٧%.

أدت إضافة السماد العضوى إلى زيادة قليلة فى محصول الحبوب فى الموسمين. عند خلط السماد العضوى والفوسفوجيبسيم. إنعكس ذلك على تحسن محصول الحبوب. فى حالة السمادين كما زاد من كفاءة دور السماد العضوى. تشير النتائج إلى تميز معاملة (النيتروجين + ٤ ميجا جرام/فدان + ٩ ميجا جرام من السماد العضوى) حيث أعطيت أعلى محصول ذرة (٤,٥٥ ميجا جرام/فدان).

أدت إضافة اليوريا والفوسفوجيبسيم والسماد العضوى ــ لزيادة وزن المائة حبة ذرة عن معاملة المقارنه فى موسم ١٩٩٩ وليس فى موسم ١٩٩٨.

إضافة الفوسفوجيبسيم مع السماد العضوى فى الموسمين أدى إلى زيادة معنوية فى محتوى الحبوب من النيتروجين مع استخدام السمادين. لم يضاف للتجربة فى الموسمين أى سماد فوسفاتى ولوحظ أنه بعد إضافة الفوسفوجيبسيم فى ثلاث مستويات قد أدت إلى زيادة محتوى الفوسفور فى حبوب الذرة ٨,٨١ ، ١١,٥٢ ، ١٢,٣١ كجم فوسفور/فدان عن معاملة المقارنة (٧,٥٧كجم فوسفور/فدان) مع سماد اليوريا. وارتفع أيضا محتوى الفوسفور مع إضافة السماد العضوى فى حالة اليوريا وكبريتات الأمونيوم فى الموسمين.

إضافة الفوسفوجيبسيم مع وجود السماد العضوى وللموسمين ومع استخدام السمادين ــ أدت إلى زيادة جوهرية فى كل من الفوسفور والنيتروجين الميسر بالتربة.