

# Relationship between The Amount of Available P and Manure Application by Calcareous Soils

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## ABSTRACT

The objectives of this study were to measure the residual  $\text{NaHCO}_3$ -extractable P resulting from manure applications at high rates and to contrast the  $\text{NaHCO}_3$ -extractable P levels for manure vs inorganic P fertilizers.

When inorganic P was applied annually at a rate of 206 kg/Feddan at the (0 to 30 cm) depth of 2 years, the  $\text{NaHCO}_3$ -extractable P was increased from 17 to 32 ppm in soil. The application of 42 kg/Feddan annually of P as triple superphosphate of 2 years before planting spinach (September-October) was effective for increasing  $\text{NaHCO}_3$  extractable P during the spinach-growing season (November, 2011) as applying 206 kg/Feddan of P in May or June each of 2 years.

High rates of P (2245 kg/Feddan) applied from manure resulted in high levels of  $\text{NaHCO}_3$ -extractable P up to 378 ppm. Total application of more than 152 tons/Feddan of manure (1123 kg P/Feddan) resulted in movement of P in soil (30 to 60 cm). The increased level of  $\text{NaHCO}_3$ -Extractable P from a manure application (treatment 152 B) was still evident in the 0 to 30 cm depth, 6 years after manure application had ceased.

The application of 165 kg P/Feddan as triple superphosphate for each of 2 years increased the  $\text{NaHCO}_3$ -extractable P over the control by 12 ppm (November, 2011). In comparing, the application of 141 kg P/Feddan from applied manure each of 2 years increased the  $\text{NaHCO}_3$ -extractable P over the control (after harvest in 2007) by 101 ppm.

**Key words:** Organic phosphorus, nutrient movement,  $\text{NaHCO}_3$ -extractable P.

## INTRODUCTION

In recent years, the amount of manure generated at large feedlots on small areas of land has increased. Manure has become a liability in many areas instead of an asset because feedlot operators must pay for its removal. The cost and energy involved in commercial fertilizer production, however, makes it imperative that utilize manure as a fertilizer.

Comparatively little is known about the long-term effects of applying large amounts of manure to irrigated desert soils. Meek *et al.* (1974) studied the effect of large applications of manure on the movement of nitrate and carbon in irrigated desert soil. This manuscript summarizes changes in available  $\text{NaHCO}_3$ - extractable phosphorus (P) caused by large applications of manure

to calcareous soils.

Several researchers have reported that manure increases the  $\text{NaHCO}_3$ - extractable P in calcareous soils and that this increase may persist for many years after manure applications have stopped. In a field experiment, Abbot and Tucker (1973) measured an increase in  $\text{NaHCO}_3$ -extractable P in December 1968 from an application of 22 metric tons/ha of manure in 1965 and again in 1967 but detected no increase in 1968 when 22 metric tons/ha of manure was applied in 1965 only. Olsen *et al.* (1954 a and b) in a greenhouse experiment found that application of 27 metric tons/ha of manure each year from 1912 to 1950 increased the  $\text{NaHCO}_3$ -extractable P, compared to the control, by 64 ppm and 122 ppm for two calcareous soils. Pratt *et al.* (1956) in a field experiment measured an increase in  $\text{NaHCO}_3$ -extractable P (1927-1955) from 6 to 69 ppm when manure was applied at the rate of 19 metric tons/ha from 1927 to 1939, and 57 metric tons/ha from 1939 to 1955. Abbot and Tucker (1973) found that manure applied in 1965 and 1967 increased the P uptake by alfalfa 35% over the control in 1970 but they did not measure  $\text{NaHCO}_3$  extractable P levels in the soil.

Organic matter (especially manure) increases the movement of P whereas application of inorganic fertilizer generally does not increase its movement (Hannapel *et al.*, 1964 a and b; and Rolston *et al.*, 1975; EL-Sayed, 2003; EL-Sayed *et al.*, 2001(a and b) and EL-Sayed, 2002 (a, b and c). Hannapel *et al.* (1964 b) found that Organic matter increased P movement in calcareous soils, and they suggested that this movement was associated with movement of microbial cells and cellular debris. Rolston *et al.* (1975) found that organic phosphate compounds may be moved greater distance's into soil than is possible with inorganic phosphates. Singh and Jones (1976) found that poultry manure increased P in solution and decreased its sorption by the soil.

Field and greenhouse studies have been utilized to evaluate the effect of long term-low rate manure applications on  $\text{NaHCO}_3$ -extractable P in calcareous soils (Olsen *et al.*, 1954 a and b; Pratt *et al.*, 1956; EL-Sayed, 1995 (a, b, c and d) and EL-Sayed, 1999). Other field studies have measured the effect of manure applications at high rates of  $\text{NaHCO}_3$ -extractable P in

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calcareous soils, but studies were conducted for only a few years.

The objectives of these study were to: (i) evaluate the effect of monitor for 6 years with the residual  $\text{NaHCO}_3$ -extractable P content resulting from manure applications at high rates and (ii) compare the  $\text{NaHCO}_3$ -extractable P levels for manure vs. inorganic P fertilizers.

### MATERIALS AND METHODS

The study was conducted on a calcareous soil at Nubaria Agriculture Research Station, at Alexandria, from 2000 to 2012. The soil is classified as a Typic Torrifluent, hyperthermic family according to Soil Survey Staff (1994), and the top 30 cm of soil contained 1.1 % organic matter, saturated soil paste were 7.9 pH; 12%  $\text{CaCO}_3$ ; and it had a cation exchange capacity of 25 meq/ 100 g. The soil texture was clay in the (0 to 30 cm) depth, silty clay loam in the (30 to 90 cm) depth and silt loam in the (90 to 150 cm) depth. The clay fraction was mainly montmorillonite. The infiltration rate of the soil was about 0.19 cm/hr under saturated conditions (Page *et al.*, 1982). Plots were 12.3 by 1 2.3 m and a distance of 6.2 m was maintained between plots.

Manure was applied in January or February for 10 years (2000-2009) with total application rates ranging from 0 to 303 tons /Feddan, as indicated in Table (1). The average composition of the manure, on an *oven-dry* basis, was; 17.6% water, 2.4% total N, 0.8% P, 58.5% organic matter, 1.2% Na, and 2.2% K. An application of 76 tons/ Feddan of manure (17.6 % water) would contain 562 kg P/Feddan. Each plot was *divided* into ( 6 to 9) subplots, then the correct amount of manure was added and mixed uniformly using a shovel and rake. Each treatment was replicated four times (Steel and Terrie, 1982 and SAS, 1988).

The plots were cropped each year except 2012, when the field was left fallow for watergrass control. All crops were adequately fertilized with N. Phosphorus fertilizer is applied to vegetable crops at Nubaria Agriculture Research Station, but not to sorghum. There was a reduction in yield of sorghum (*Sorghum bicolor* L.Moench) when manure was applied at yearly rates of 152 tons/ Feddan .In 2007, only P fertilizer was applied to all plots of spinach at a rate of 56kg P/ Feddan in (2000, 2007, 2008, 2009, and 2010). Sorghum (*Sorghum bicolor* L. Moench) *variety* Giza 113 was planted in March or April and harvested in August. Spinach (*Spinacia oleracea* L.) was planted in the field in October 2007 and 2011 and harvested in January of the following year. In 2011 barely (*Hordeum vulgare* L) *variety* Giza 124 was planted in January and harvested in May.

Soil samples were taken (0 to 30cm and 30 to 60 cm) depths at the beginning of the experiment and each year after harvest. Analyses were conducted on a composite soil sample from each plot and each depth which consisted of three cores in 2000 and 2007 and eight cores in (2008-2012).

To determine the P moving in the soil, solution samples were collected with ceramic cups during one irrigation in 2009 by the procedure used by Meek *et al.* (1974). One sample was collected at each of the four depths (30, 60, 90 and 150 cm) from three plots (0, 152 Band 303 E treatments). An aliquot of the sample was digested with persulfate solution (American Public Health Association, 1976) before analysis to release organically bound P.

A supplemental study was conducted in a field of the same soil type (saturated soil paste of 7.9 pH, 12%  $\text{CaCO}_3$ ) located about 0.6 km from the main field. Initially, this field contained approximately one-half the  $\text{NaHCO}_3$ - extractable P of the manured field (6 ppm compared to 10 ppm).

**Table 1. Manure treatments at different years**

Treatment code*	P applied kg/feddan	Tons/Feddan			
		2000	2007	2008	2009
0A	0	0	0	0	0
76 B	562	76	0	0	0
76 E	562	19	19	19	19
114D	842	38	38	38	0
152 B	1123	152	0	0	0
227 C	1684	76	152	0	0
227D	1684	76	76	76	0
303 E	2245	76	76	76	76**

\* Total manure application (2000-2009), in tons per Feddan for A = 0, B = 1, C = 2, D = 3, and E = 4 applications.

\*\*This treatment was split in 2009 so data are based on two plot values instead of four from 2009.

Triple superphosphate was broadcasted at rates of 0, 42, 83, 124, 165 and 206 kg /feddan to plots 12.3 m square in May of 2010 and June 2011. After the fertilizer was applied, the plots were irrigated three times during the summer and not cropped. The field was prepared and spinach (*Spinacia oleracea* L.) was planted in October 2010 and September 2011 and adequately fertilized with N. In one treatment, 42 kg P/Feddan was applied in the fall (instead of May or June) just before planting the spinach. Each treatment was replicated six times. Soil samples (0 to 30 and 30 to 60 cm) depths were taken in August 2010, April and November of 2011, and January 2012. Eight soil cores were taken from each plot and one composite sample from each plot at each depth was analyzed.

The colorimetric ascorbic acid method (Watanabe and Olsen, 1965) was used to measure P in  $\text{NaHCO}_3$ -extracts (Olsen *et al.*, 1954 a and b), and in soil solutions. Procedures in the salinity handbook (U.S. Salinity Laboratory Staff., 1954) were used to determine  $\text{CaCO}_3$  (by gravimetric loss of  $\text{CO}_2$ ), organic matter, and cation exchange capacity.

### RESULTS and Discussion

#### $\text{NaHCO}_3$ -extractable P at the (0 to 30 cm) depth after inorganic fertilizer applications:

The application of high rates of inorganic P fertilizer resulted in small increases in  $\text{NaHCO}_3$ -extractable P (Table 2). The P level in the soil (0-30 cm) was 32 ppm or less even when 206 kg P/Feddan was applied annually of 2 years. Inorganic P applied in the summer of 2010 was fixed rapidly and there were only small increases in  $\text{NaHCO}_3$ -extractable P in August of 2010 from treatments applied in May 2010. The applying of 165 kg /feddan or more in May to significantly increase  $\text{NaHCO}_3$ -extractable P in August as compared with the control (EL-Sayed and Salem, 2001). As much or more  $\text{NaHCO}_3$ -extractable P was present in November 2011

**Table 2.  $\text{NaHCO}_3$ -extractable P in soil ( 0-30 cm) samples taken from plots treated with triple superphosphate fertilizer**

P applied kg/Feddan		$\text{NaHCO}_3$ - extractable P, ppm			
2010	2011	August 2010	April 2011	November 2011	January 2012
0 (May)	0 (June)	6a*	11a	17a	15a
42 (May)	42 (June)	8 ab	13 ab	23 bc	20 ab
83 (May)	83 (June)	9 abe	15 bc	25 bc	24 bc
165 (May)	165 (June)	10 be	15 abc	28 cd	27 c
206 (May)	206 (June)	12 cd	17 c	32 d	30 c
42 (October)	42 (September)	7 ab**	26 d	32 d	24 bc

\* Column values within years followed by same letter are not significantly different at the 5% level.

\*\* No P fertilizer had been applied at this date.

from application of 42 kg P/Feddan just before planting as from 206 kg P/Feddan which applied 4 or 5 months earlier (Ahmad and EL-Sayed, 2002 and EL-Sayed, 1989 and 2001).

#### **Available P at the (0 to 30 cm) depth after manure applications:**

The application of manure caused large increases in the amount of  $\text{NaHCO}_3$ -extractable P (Table 3). In the control, the soil (0-30 cm) contained (10-28) ppm  $\text{NaHCO}_3$ -extractable P (2007-2012). The large variation between years was probably different amounts of crop residues due to the different sampling times (EL-Sayed and Ahmad, 2001). In contrast to the control treatment, some of the manure treatments contained  $\text{NaHCO}_3$ -extractable P up to 378 ppm. Manure affected  $\text{NaHCO}_3$ -extractable P for several years; for, example, treatment 152 B (1123 kg P/Feddan), a plot that received manure only in 2000, still had about seven times more  $\text{NaHCO}_3$ -extractable P than the control in 2012. After manure applications had ceased,  $\text{NaHCO}_3$ -extractable P from application of manure decreased about 15% each year. The application of 76 tons/Feddan in 2000 only (76 B) or the application of 19 tons/Feddan for 4 years (76 B), resulted in the same  $\text{NaHCO}_3$ -extractable P level in 2012. This was also true of treatments 227 C and 227 D (EL-Sayed, 1995 a,b,c and d and EL-Keiy and EL-Sayed, 1991).

#### **$\text{NaHCO}_3$ -extractable P at the (30 to 60 cm) depth after manure applications:**

Manure applications increased the  $\text{NaHCO}_3$ -extractable P in soil (30 to 60 cm) as shown in Table 4. The control plots contained 2-8 ppm  $\text{NaHCO}_3$ -extractable P, whereas the highest rate of manure application increased the P level to 44 ppm. By 2012, there was no difference in  $\text{NaHCO}_3$ -extractable P between the check and treatments of less than 227 tons/Feddan (1684 kg P/Feddan).

**Table 3. The amounts of NaHCO<sub>3</sub> -extractable P from soil (0-30 cm) depth in soil samples taken from manure-treated plots after harvest**

Treatment code**	P applied kg/Feddan	NaHCO <sub>3</sub> - extractable P,ppm					
		2007	2008	2009	2010	2011	2012
0A	0	10a*	22a	10a	18a	28a	15a
76B	562	110c	107b	70 bc	61b	70b	54b
76E	562	68abc	102b	99cd	109c	69b	59b
114D	842	91bc	173c	123d	137c	89c	72b
152B	1123	194d	190c	121d	124c	104c	95c
227C	1684	316e	275d	196 e	216 d	116 d	145 d
227 D	1684	197 d	264 d	239 f	230 d	174 e	146 d
303 E***	2245	298e	285d	278 g	359 e	255f	238 e

\*Column values within years followed by same letter are not significantly different at the 5% level.

\*\*Total manure application (2000-2009) ; in tons per Feddan for A = 0, B = 1, C = 2, D =3 and E=4 applications.

\*\*\* This treatment was split in 2009 so data are based on two plot values instead of four from 2009.

**Table 4. NaHCO<sub>3</sub>-extractable P from soil (30-60 cm), samples taken from manure-treated plots after harvest**

Treatment code**	P.applied kg/Feddan	NaHCO <sub>3</sub> -extractable P. ppm			
		2009	2010	2011	2012
0A	0	4a*	5a	2a	8a
76B	562	4a	6ab	4ab	11a
76E	562	5a	8ab	3ab	10a
114D	842	6ab	8ab	4ab	15a
152B	1123	8bc	9b	5ab	16a
227C	1684	11cd	15c	7b	40bc
227D	1684	13d	17c	12c	32b
303E***	2245	16e	16c	14c	44c

\* Column values within years followed by same letter are not significantly different at the 5% level.

\*\*Total manure application (2000-2009) in tons per Feddan for A = 0, B =], C = 2, D = 3, and E = 4 applications.

\*\*\* This treatment was split in 2009 so data are based on two plot values instead of four From 2009.

Plots Treated with 227 tons/Feddan or more had large increases in NaHCO<sub>3</sub>-extractable P from 2011 to 2012. However, the application of inorganic P fertilizer did not increase NaHCO<sub>3</sub>-extractable P at the 30 to 60 cm soil depth (Fargallah and EL-Sayed, 2002, Fatma *et al.*, 2013).

#### **P contents of soil solutions:**

Manure applications increased the P content of soil solutions (Table 5). Soluble P content of the soil solutions in the check and 152 B treatments was generally low. The highest manure application increased the P level between the 30 and 150 cm depths. Similar values for the persulfate digested samples and the undigested samples indicated that the P moved in a soluble organic or inorganic form and not as part of a complex organic carbon compound. The persulfate digestion would have been expected to break down the complex organic compounds and release P in a soluble form (EL-Sayed, 2002 a, b and c and Ghaly and EL-Sayed, 1997).

Manure applications increased NaHCO<sub>3</sub>- extractable soil P to high levels in the 0 to 30 cm depth and maintained the P above 51 ppm for 6 years without additional manure applications. In addition, manure caused P movement and an increasing in NaHCO<sub>3</sub>-extractable P at the (30 to 60 cm) depth. Analysis of soil solution samples indicated that the P was moving in the soil solution (EL-Sayed *et al.*, 2001 a and b and Abdel-Mawly and EL-Sayed, 1999). These data indicated that NaHCO<sub>3</sub>-extractable P remained higher from manure applications than from applications of inorganic phosphorus fertilizer when P application rates were similar (EL-Sayed,2003) .When 141 kg P was applied in the manure (19 tons /Feddan per year) in 2000 and 2007, the amount of NaHCO<sub>3</sub>-extractable P was 68 ppm after harvest in August of 2007.

When 165 P/Feddan were applied as triple superphosphate in 2010 and 2011, the NaHCO<sub>3</sub>-extractable P concentration was 28 ppm in November 2011.

**Table 5. Soluble P collected using ceramic cups in 2009**

Treatment code*	Depth cm	P .ppm	
		Soil solution	Persulfate-digested Soil solution
OA	30	0.3	0.2
	60	0.2	0.2
	90	0.2	0.2
	150	0.2	0.0
152B	30	2.1	2.1
	60	0.2	0.2
	90	0.2	0.0
	150	0.4	0.3
303E	30	14.3	13.3
	60	5.1	3.4
	90	3.6	3.3
	150	2.7	2.2

\* Total manure application (2000-2009); in tons per Feddan for A = 0, B = I, and E = 4 applications.

In many areas, it would cost less to apply manure at the rate of 19 tons/Feddan for each of 4 years and did not apply P for the next 4 years than the current fertilizer practice which is to apply P fertilizer at the rate of 47 kg P/Feddan each year for winter crops. In 2013 at Nubaria Agriculture Research Station at Alexandria, applying the manure (76 tons/Feddan with 7 km of the feedlot) would cost low pounds as compared with pounds for applying 47 kg P/Feddan per year for 8 years (low pounds/kg of P). In addition, the manure would supply N to the crops for at least 4 of the 8 years (EL-Sayed, 1998 a and b; 1996; 1997 and 1999; Ahmed, 2013).

### CONCLUSIONS

The application of 19 tons / Feddan of manure per year for 4 years will not usually result in a salinity problem in 'the desert for spinach because the manure can be applied in the spring and leaching can take place during summer.

If manure is applied for many years, then at some time the fixing capacity of the soil should be satisfied, but, at Nubaria Agriculture Research Station at Alexandria with soil containing 11-16% CaCO<sub>3</sub> this may require many years.

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## الملخص العربي

### العلاقة بين الفوسفور المتيسر والاسمدة العضوية المضافة في الاراضى الجيرية

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اسمدة عضويه وكنتيجه لذلك فقد استخلص مستوى مرتفع من الفوسفور ببيكربونات الصوديوم بلغ 378 جزء في المليون. الاضافه الكليه لاكثر من 152 طن سماد عضوى /فدان (1123 كجم فوسفور/ فدان) نتيجته لتحرك الفوسفور من عمق 30 سم حتى عمق 60 سم. زياده مستوى الفوسفور من السماد العضوى المضاف والمستخلص ببيكربونات الصوديوم كانت غير متحركه واضحه وجليه عند عمق صفر سم حتى عمق 30 سم لمدة ستة اعوام بعد اضافه الاسمده العضويه حيث توقفت.

اضافة 165 كجم فوسفور/ فدان على صورة سوبر الفوسفات الثلاثى كل عام لمدة عامين حيث ادت الى زياده الفوسفور المستخلص ببيكربونات الصوديوم عن الكنترول بمقدار 12 جزء في المليون (نوفمبر، 2011). وعلى العكس من ذلك فان اضافه 141 كجم فوسفور/فدان من السماد العضوى المضاف (معامله 76B) كل عام لمدة عامين حيث ادت الى زياده الفوسفور المستخلص ببيكربونات الصوديوم عن الكنترول بمقدار 101 جزء في المليون (بعد الحصاد فى عام 2007).

المهدف من هذه الدراسة هى قياس المتبقى من الفوسفور بالاستخلاص ببيكربونات الصوديوم نتيجة لاضافة الاسمده بمعدلات مرتفعة وعلى العكس من ذلك فان مستويات الفوسفور المستخلص ببيكربونات الصوديوم للاسمده العضويه مقارنة بالاسمدة الفوسفاتية الغير عضويه.

عند اضافه الفوسفور الغير عضوى بمعدل 206 كجم/ فدان كل عام لمدة عامين فان الفوسفور المستخلص ببيكربونات الصوديوم يزداد من 17 الى 32 جزء في المليون عند اعماق صفر؛ 30 سم. اضافه الفوسفور بمعدل 42 كجم/ فدان على صورة سوبر الفوسفات الثلاثى كل عام لمدة عامين قبل زراعة السبانخ (سبتمبر - اكتوبر) كان مؤثرا لزيادة الفوسفور المستخلص ببيكربونات الصوديوم خلال موسم نمو السبانخ (نوفمبر؛ 2011) عند اضافه الفوسفور بمعدل 206 كجم/فدان فى مايو او يونيه كل عام لمدة عامين.

اضافة الفوسفور بمعدلات مرتفعه (2245 كجم/فدان) على صورة