( )   , ( )

*

.

(   )

.   .

.   % /   % / $NaBPh_4$

$NaBPh_4$ $(r^2= /   p < /   )$

.

(SE) (r^2)

.(/   / r^2)

. $(r^2=0.99)$

.

:

(   )
.(Chute and Quirk, 1967; Grimme,   1974)

.

Cox and)
.(Joern, 1997   .

:

$(NH_4OAc\ 1M)$

.

;Richards Barber and Mathews, 1962)
et al., 1994; Mengel and Uhlenbecker, 1993 *et al*., 1988;
.(Rahmatullah

McLean and)
.(Watson, 1985   .(Cox *et al*., 1999)

Stehouwer and)

(Johnson, 1991

.(Cox *et al*, 1996)   shahbazikarim@yahoo.com :   *

، ( )

Portela,)

(Eckert and Watson, 1996; 1993

(Cassman *et al.*, 1990)

( ) Dhillon and Dhillon .

0.3*M* NaBPh₄   ( ) Pratt

(   )

.

HNO₃   H₃O⁺

.   .   K

.

%   ( )Smith *et al.*   .(Cox *et al*, 1996)

NaBPh₄   Smith and Scott   (NaBPh₄)   ( )

Carey and Metherel   ( ) Cox and Joern .

( )   K⁺   BPh₄⁻   .

Cox and   .   (KBPh₄)

( )Joern   NaBPh₄

KBPh₄

.(Cox *et al*, 1999)

( ) Carey and Metherel .   KBPh₄

BPh₄⁻   Hg²⁺

NaBPh₄   ( ) Cox *et al.* .

( ) Reed and Scott

NaBPh₄   BPh₄⁻   .

Hg²⁺   Cu²⁺

.   .(Cox *et al.*,1999; Cox and Joern, 997)

NaBPh₄   NaBPh₄   ( )

.

( )

.

( )

.

(Chapman,1965) pH = /

Knudsen *et al.*

.   ( )

.

Rahmatullah *et al.*,)

Sadusky *et al.*, Mengel and Uhlenbecker, 1993; 1994

.(Martin and Sparks, 1983   Havlin *et al.*, 1985; 1987;

Dhillon   ( )Towfighi

( ) Smith *et al.*   ( ) and Dhillon

( )Towfighi .

...   :

.

0.5M CaCl$_2$
)

.   KBPh$_4$.(AgNO$_3$

KCl   .

(2M NaCl-0.01M NaEDTA-0.2M NaBPh$_4$)

.   Cox $et\ al.$ (   ) Reed and Scott

.   .   (   )

)   (   )

((2M NaCl-0.01M NaEDTA-0.2 M NaBPh$_4$)

/

.   . $/$ $/$ $/$)

(r^2)   (

.   (SE)

:

$$SE = \left[\sum \left(q - q^*\right)^2 / (n-2) \right]^{1/2}$$

.   CuCl$_2$

q^* q

n   .   HCl 50%

.

(Knudsen $et\ al.$, 1982)

-                          .   ( )   )   (   )

2M NaCl-)   (

(CEC)   (0.01M NaEDTA-0.2 M NaBPh$_4$

.   (CCE)   .

SP (g kg^{-1})	CCE (g kg^{-1})	OC (g kg^{-1})	Clay (g kg^{-1})	CEC (Cmol$_c$ kg^{-1})	EC (dSm^{-1})	pH	
		/		/	/	/	Typic Haplocambids
		/		/	/	/	Typic Haploxerepts
		/		/	/	/	Typic Calcixerepts
		/		/	/	/	Typic Haploxerepts
		/		/	/	/	Typic Xerofluvents
		/		/	/	/	Typic Calciustepts
		/		/	/	/	Typic Calciustepts
		/		/	/	/	Xeric Haplocalcids
		/		/	/	/	Xeric Torrifluvents
		/		/	/	/	Typic Endoaquepts
		/		/	/	/	Typic Endoaquolls
		/		/	/	/	Typic Haploxerolls

.(

( )

$/$ $/$ $/$)

)

، ( )

( ) Cox *et al*. .(

NaBPh$_4$

HNO$_3$

pH

. ( ) KBPh$_4$.

. NaBPh$_4$ NaBPh$_4$.

KCl ( )

KCl

. ( ) Murashkina *et al*. .(r^2= / P< /)

NaBPh$_4$

p< /)

.(r^2 = / p< /) (r^2= /

( )	(mg)
/	
/	

NaBPh$_4$ ( )

.

Cox and ( )Towfighi .

( )Carey and Metherel ( ) Joern

.

)

(

.

.

(mg kg^{-1})

	NaBPh$_4^†$	M NH$_4$OAc
	/	/
	/	/
	/	/
	/	/
	/	/
	/	/
	/	/
	/	/
	/	/
	/	/

† پتاسیم غیرتبادلی استخراج شده با استفاده از محلول NaBPh$_4$ طی ۸ روز.

.

NaBPh$_4$

y = 2.36x + 202.49
r^2 = 0.78***

( )

...   :

.

.   ( )   .

(   ) Scott and Reed

.

( )   .

/

/   /

.

(   )   ( )

.

.
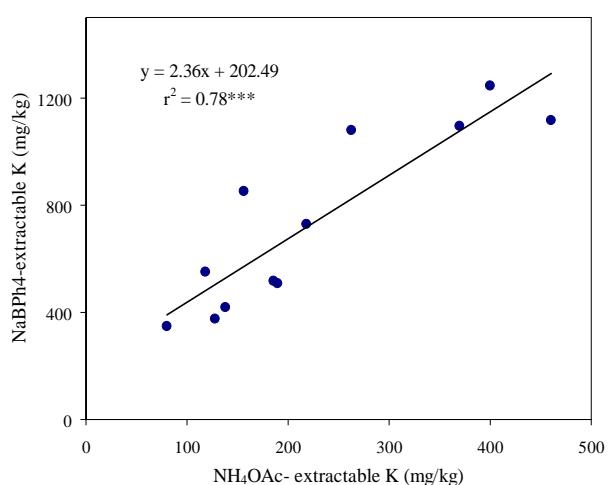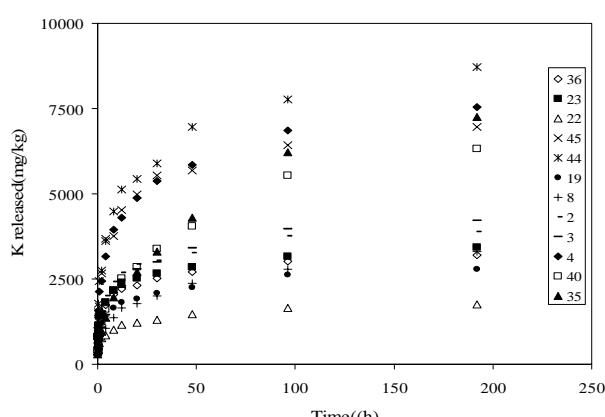
Reed and .(Reed and Scott, 1966)

(   ) Scott

%   .

(   )Bailly,   .   Barber and)

%   Mengel and   Richards *et al*., 1988; Mathews, 1962

(   ) Reed and   Scott .   Cox *et* Rahmatullah *et al*., 1994; Uhlenbecker, 1993;

.(Towfighi,1999; *al*.,1999;

%

% /   .

106 mg K/10

.(Reed and Scott, 1962)   g   .

.(Reed and Scott, 1962)   %

پتاسیم قابل استخراج با **1M NH4OAc**

(   )

.

:   .   NaBPh₄

$(K_0 - K_t) = a - bt$ ( )   b   a

NaBPh₄

$$q = (1/\beta)\ln\alpha\beta + (1/\beta)\ln t \qquad (\ )$$

$$Ln(K_0 - K_t) = a - bt \qquad (\ )$$

$$1/(K_0 - K_t) = a + bt \qquad (\ )$$

β α t   q

(b)   . K_0

t t K_t

.   b a

.

.( )

r^2 SE
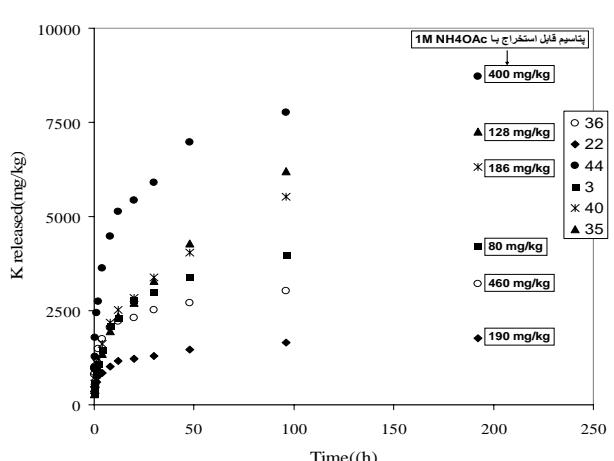
.(a   )

Polyzopoulos *et*)

.(*al*., 1986; Aharoni and Ungarish, 1976

$[q=(1/\beta)\ln\alpha\beta+(1/\beta)\ln(t+t_0)]$ t_0

Chien and . $(t+t_0)$ q

$t_0=0$ ( ) Clayton

α

β

.

:

$$q = at^b \qquad (\ )$$

b a

.

$$\ln q = \ln a + b\ln t \qquad (\ )$$

$r^2)$

(/   /   /

(SE)

( )   b   .(c   )

b   .

( ) Cox and Joern

.(Havlin *et al*., 1985)   Great Plains

:

$$q = a + bt^{1/2} \qquad (\ )$$

.   b   a

.   ( )

( )

پتاسیم کل

14%

پتاسیم آزاد شده با NaBPh₄

Soil No. 36   (a)

K released(mg/kg)

Time(h)

پتاسیم کل

48%

پتاسیم آزاد شده با NaBPh₄

Soil No. 44   (b)

K released(mg/kg)

Time(h)

NaBPh₄

b   **a**

Low,)

.(1960

(Sparks, 1998)

:
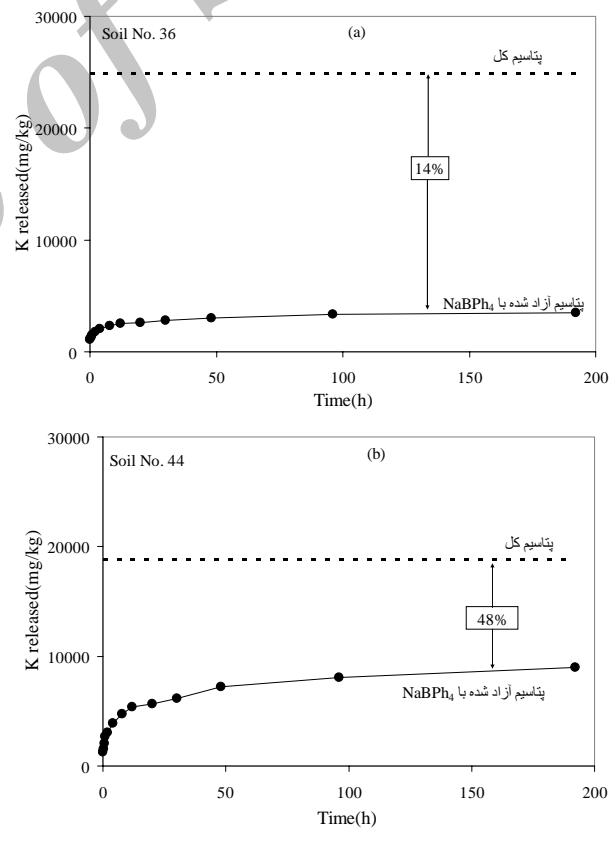
Cox and Dhillon and Dhillon; 1992) NaBPh₄

Ca^{2+} (Joern, 1997;

(Jardine and Sparks, 1984)   .(Jardine and Sparks, 1984)

Bolt .   (Bolt *et al.*, 1963)

( ) *et al*

$(b = 239.9\text{-}1711.7 \ mg \ kg^{-1}h^{-1/2})$

$(b = 80.1\text{-}662.8 \ mg \ kg^{-1}h^{-1/2})$

.(

(a)
▲ soil No. 8
○ soil No. 19
● soil No. 4

$1/[(K\text{-}k_0), mg/kg]$

$r^2 = 0.940$
$r^2 = 0.993$
$r^2 = 0.968$

Time(h)

▲ soil No. 8
○ soil No. 19
● soil No. 4

6000
4000
2000

$r^2 = 0.985$
$r^2 = 0.981$
$r^2 = 0.986$
$r^2 = 0.997$
$r^2 = 0.971$
$r^2 = 0.992$

K released(mg/kg)

$[Time(h)]^{1/2}$

NaBPh₄
SE r^2

(b)
▲ soil No. 8
○ soil No. 19
● soil No. 4

K released(mg/kg)

$r^2 = 0.971$
$r^2 = 0.979$
$r^2 = 0.932$

Ln[Time(h)]

.( )   NaBPh₄

SE r^2

NaBPh₄

(c)
▲ soil No. 8
○ soil No. 19
● soil No. 4

Ln[K released(mg/kg)]

$r^2 = 0.983$
$r^2 = 0.991$
$r^2 = 0.995$

Ln[Time((h)]
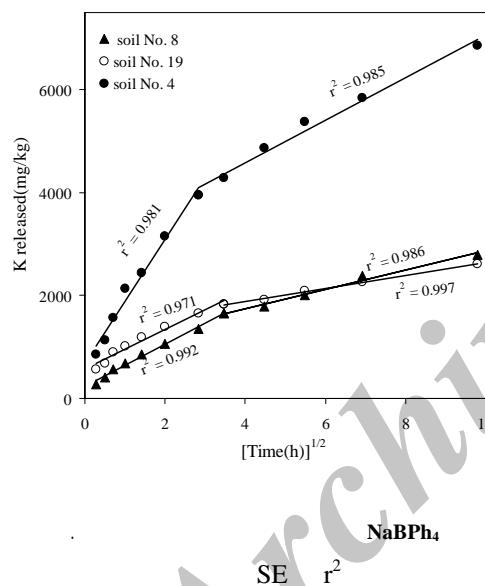
.(Jardine and Sparks, 1984; Chute and Quirk, 1967)

NaBPh₄

.   **c**   **b**   **a**

, ( )

.

NaBPh₄

( )		(	)				
a	b	a	b	α	β	a	b
				/		/	
				/		/	
				/		/	
				/		/	
				/		/	
				/		/	
				/		/	
				/		/	
				/		/	
				/		/	
				/		/	

(**ki**)

NaBPh₄

.

(**SE**)   –

(**r²**)
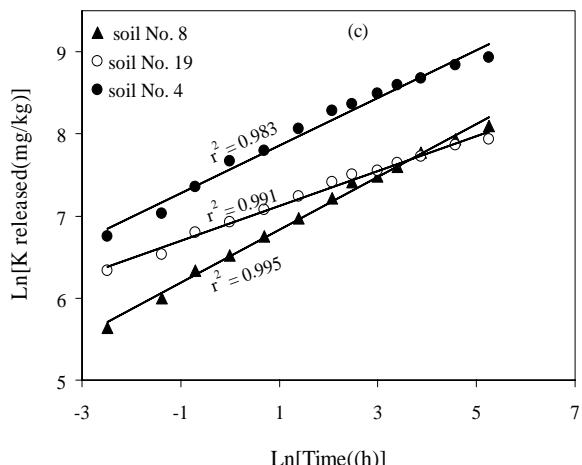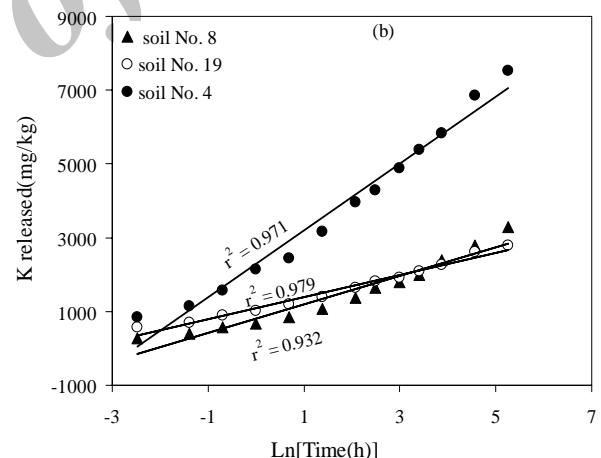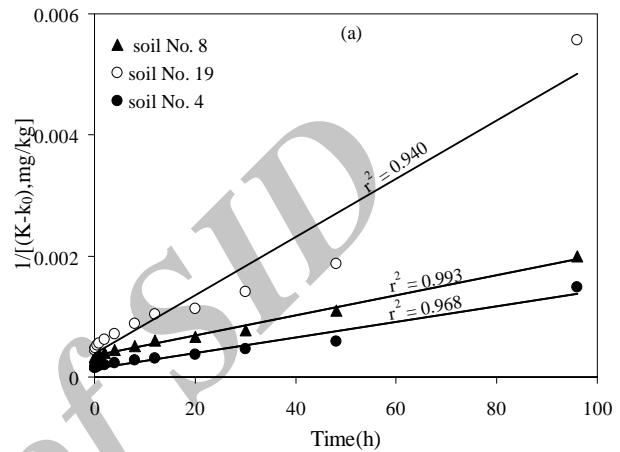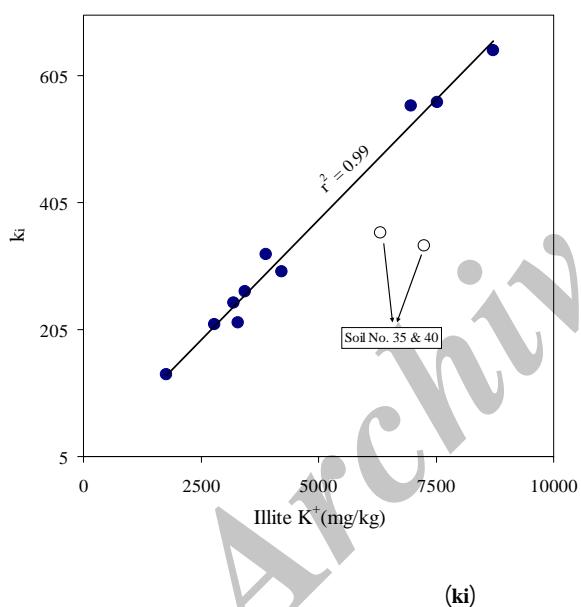
NaBPh₄

	SE	r²	
/	/	/	
/	/	/	
/	/	/	
/	/	/	
/	/	/	
/	/	/	
/	/	/	( )
/	/	/	( )

.

(b a)

( )Allen *et al.* .

(a×b)

(kᵢ)

.

)

(

NaBPh₄

.( )

Cox and Joern, 1997;Cox *et al.*,)

Havlin and Westfall 1985; Havlin *et*)   .(1999

b a   (*al.*, 1985

b

.( )

(b a)

(b)

REFERENCES

Aharoni, C., and Ungarish. M. (1976). Kinetics of activated chemisorption. Part I. The non-Elovichian part of the isotherm. *J. Chem. Soc. Faraday Trans*. 72:400-408.

Allen, E. R., Hossner, L. R. Ming, D. W. and Henninger. D. L. (1996). Release rates of phosphorus, ammonium, and potassium in clinoptilolite-phosphate rock system. *Soil Sci. Soc. Am. J*. 60:1467-1472.

Bailly, F. (1963). Comparison of some methods for the determination of potassium release from minerals. Z. Planzenernahr. *Dung. Bodenkunde*. 102:17-28.

Barber, T.E., & Mathews. B. C. (1962). Release of non-exchangeable soil potassium by resin-equilibration and its significance for crop growth. *Can. J. Soil Sci*. 42:266–272.

Bolt, G. A., Summner, M. E. and Kamphort. A. (1963). A study of the aquilibria between three categories of potassium in an illitic soil. *Soil Sci. Soc. Am. Proc*. 27:294-299.

Carey, P. L., and Metherell. A. K. (2003). Rates of

release of non-exchangeable potassium in New Zealand soils measured by a modified sodium tetraphenyl-boron method. *New Zealand Journal of Agricultural Research.* 46: 185–197

Cassman, K.G., Bryant, D.C. and Roberts. B.A. (1990). Comparison of soil test methods for predicting cotton response to soil and fertilizer potassium on potassium fixing soils. *Commun. Soil Sci. Plant Anal.* 21:1727–1743.

Chapman, H. D. (1965). *Cation exchange capacity.* P.891-902.In C. A. Black et al. (ed). Methods of soil analysis, part 2, ASA, Madison,WI.

Chien, S. H. and Clayton. W. R.(1980).Application of Elovich equation to the kinetics of phosphate release and sorption in soils. *Soil Sci. Soc. Am. J.*44:265-268.

Chute, J. H., and Quirk. J. P. (1967). Diffussion of potassium from mica-like clay minerals. *Nature* 213:1156-1157.

Cox, A. E., Joern, B. C. and Roth. C. B. 1996. Nonexchangeable ammonium and potassium in soils with a modified sodium tetraphenylboron method. *Soil Sci. Soc. Am. J.* 60:114-120.

Cox, A.E., and Joern, B.C. (1997). Release kinetics of nonexchangeable potassium by sodium tetraphenylboron in midwestern soils. *Soil Sci.* 162: 588–598.

Cox, A. E., Joern, B. C., Brouder, S. M. and Gao. D. (1999). Plant- available potassium assessment with a modified sodium tetraphenylboron method. *Soil Sci. Soc. Am. J.* 63:902-911.

Dhillon, S. K., and Dhillon. K. S. (1992). Kinetics of release of potassium by sodium tetraphenylboron from some top soil samples of red (alfisols), black (vertisols) and alluvial (inceptisols and entisoils) soils of India. *Fert. Res.* 32:135-138.

Eckert, D.J., and Watson M. E. (1996). Integrating the Mehlich extractant into existing soil test interpretation schemes. *Commun. Soil Sci. Plant Anal.* 27:1237–1249.

Grimme, H. (1974). Potassium release in relation to crop production. Proc. 10th Int. *Colloquium, Potash Institute*, Bern,pp.131-136.

Havlin, J. L., and Westfall, D. G. (1985). Potassium release kinetics and plant response in calcareous soils. *Soil Sci. Soc. J.*49:366-370.

Havlin, J. L., Westfall, D. G. and Olsen. S. R. (1985). Mathematical models for potassium release kinetics in calcareous soils. *Soil Sci. Soc. Am. J.* 49:371-379.

Jackson, M. L. (1956). Soil chemical analysis-advanced course: mimeo. published by the author, Madison, Wisc.

Jardine, P. M.., & Sparks, D. L. (1984). Potassium-calcium exchange in a multireactive system: I. Kinetics. *Soil Sci. Soc. Am. J.*48:39-45

Knudsen, D., Peterson, G. A. and Pratt, P. F. (1982). *Lithium, Sodium, and Potassium*. P. 225-246. In: A. L. Page(ed) Methods of soil analysis, Part 2. ASA-SSA, Madison, WI., USA.

Low, M. J. D. (1960). Koinetics of chmisorption of gases on solids Chem.. Rev.

Martin, H. W., and D. L. Sparks. 1983. Kinetics of

nonexchangeable potassium release from two Coastal Plain soils. *Soil Sci. Soc. Am. J.* 47:883-887.

McLean, E.O., and Watson, M.E. (1985). Soil measurements of plant-available potassium. p. 277–308. In. R.D. Munson. (ed.) *Potassium in agriculture*. ASA, CSSA, and SSSA, Madison, WI.

Mengel, K., and Uhlenbecker. K. (1993).Determination of available interlayer potassium and its uptake by ryegrass. *Soil Sci. Soc. Am. J.* 57:561–566.

Murashkina, M. A., Southard, R. J. and Pettygrove. G. S. (2007). Potassium Fixation in San Joaquin Valley Soils Derived from Granitic and Nongranitic Alluvium. *Soil Sci. Soc. Am. J.* 71:125-132.

Polyzopoulos, N. A., Keramidas, V. Z., Pavlatou, A. (1986). On the imitations of the simplified Elovich equation in describing the kinetics of phosphate sorption and release from soils. *Journal of Soil Science* 37: 81–87.

Portela, E. A. C. (1993). Potassium supplying capacity of northeastern Portugese soils. *Plant Soil* 154:13–20.

Pratt, P. F. (1965). Potassium. P. 1022-1030. In C. A. Black (ed.) Methods of soil analysis. Part1. Agron. Monogr. 9 ASA, Madison WI. Quirk, J. P., and J. H. Chute. 1968. Potassium release from mica-like clay minerals. 9th Int. *Congress Soil Sci.* II.671-681.

Rahmatullah, B. Shaikh, Z. Gill, M.A. and Salin. M. (1994). Bioavailable potassium in river-bed sediments and release of interlayer potassium in irrigated arid soils. *Soil Use Manage.* 10:43–46.

Reed, M. G., and Scott. A. D. (1962). Kinetics of Potassium release from biotite and muscovite in sodiumtetraphenylboron solution. *Soil Sci. Soc. Am.Proc.* 25:437-

Reed, M. G., and Scott, A. D. (1966). Chemical extraction of potassium from soils and micaceous minerals with solutions containing sodium tetraphenylboron. IV. Muscovite. *Soil Sci. Soc. Am. Proc.* 30.185-188.

Richards, J. E., Bates, T. E. and Sheppard. S.C. (1988). Studies on the potassium-supplying capacities of southern Ontario soils: I. Field and greenhouse experiments. *Can. J. Soil Sci.* 68:183–197.

Sadusky, M. C., Sparks, D. L., Noll, M. R., and Hendricks. G. J. (1987). Kinetics and mechanism of potassium release bfrom sandy Middle Atlantic Coastal Plain soils. *Soil Sci. Soc. Am J.* 51: 1460-1465.

Scott, A. D., and Reed. M. G. (1962). Chemical extraction of potassium from soils and micaceous minerals with solution containing sodium tetraphenylboron: II.Biotite. *Soil Sci. Soc. Am. Proc.* 25:41-45.

Scott, A. D., and Reed. M. G. (1962). Chemical extraction of potassium from soils and micaceous minerals with solution containing sodium tetraphenylboron: III.Illite. *Soil Sci. Soc. Am. Proc.*25:45-48.

Smith, S. J., and Scott. (1966). Extractable potassium in grundite illite: Method of extraction. *Soil Sci.* 102:115-122.

Smith, S. J., Clark, J. and Scott. A. D. (1968). Exchangeable of potassium in soils. *Int. Congr. Soil Sci. Trans.*(Adelaide, Aust.) II:661-669.

Sparks D. L. (1998). *Soil physical chemistry*. 2ⁿᵈed. Academic Press, New York.

Stehouwer, R. C., and Johnson. J.W. (1991). Soil adsorption interactions of band-injected anhydrous ammonia and potassium chloride fertilizers. *Soi, Sci. Soc. Am. J.* 55:1374-1381.

Towfighi, H. (1995).Kinetics of potassium release from paddy soils of north of Iran.1-Comparison and evaluation of first-order, zero-order and parabolic diffusion rate equation. *Iranian Journal of Agriculture Science*.38 (1), 27-41.(In Farsi).

Towfighi, H. (1999).Response of rice to potassium application in paddy soils of north of Iran. *Iranian Journal of Agriculture Science*. 29 (4), 869-882.(In Farsi).