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ORIGINAL ARTICLE

DESCRIBING KINETICS OF RELEASED PHOSPHORUS FROM AMMONIUM POLYPHOSPHATE IN CALCAREOUS SOIL

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Abstract: Lab experiment had been conducted to study the kinetics of phosphorus in the soil by using a first-order equation with time, 10g of dry soil was mixed with 100mg of the phosphate fertilizers, ammonium polyphosphate (APP), Mono-ammonium phosphate (MAP) and di-ammonium phosphate (DAP), the mixture placed to 100 ml plastic tube and then 05 N of sodium bicarbonate solution was added to the mixture and then shaken for 5, 30, 60, 120 and 150 minutes, 10 ml had been taken from the mixture and then the released phosphorus was cumulatively measured. The results showed that the highest amount of released phosphorus was achieved in the soil treated with APP fertilizer, at 150 minutes and at L2 level, at 19.71g $P.kg^{-1}$. Whereas the highest released phosphorus in the soil treated with MAP fertilizer was 14.93 mg $P.kg^{-1}$ at 5 minutes and L2. Similarly, the highest amount of soil-released phosphorus treated with DAP fertilizer was 12.42 mg $P.kg^{-1}$ at 5 minutes and L2. The results also showed that the highest value of releasing speed coefficient (Kd) for soil-released phosphorus in soil treated with APP fertilizer and for the period of the 150 minutes was 3,621 mg $P.kg^{-1}$.

Key words: Ammonium poly phosphate, Monoammonium phosphate, Diaammonium phosphate, Kinetics.

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1. Introduction

Phosphorus is a necessary and important nutrient for plant growth, which it needs in large quantities [AL-Taey *et al.* (2018), AL-Bayati *et al.* (2019)], so the importance of studying its availability in the soil, especially Iraqi soils, which are classified as calcareous soils as a result of containing large quantities of calcium minerals, as phosphorus added to a series of interactions with these minerals and calcium ions dissolved in soil solution or exchanged on clay metal surfaces is exposed to different phosphate compounds in terms of melting and crystallization degree [Mikkelsen and Leytemm (2005), Mahmood *et al.* (2020), Krishna *et al.* (2020)].

Recently, multiple (condensed) phosphate fertilizers have received increasing attention in many countries around the globe in addition to researchers in the field of soil chemistry and fertility because they contain large quantities of phosphorus [Al-Juthery *et al.* (2020), Al-Khafajy *et al.* (2020)] as well as other important nutrients such as nitrogen as well as because of their slow decomposition, which reduces their area of stabilization in the soil, where these fertilizers provide plants with many nutrients, especially phosphorus, in accordance with its growth stages [AL-Taey *et al.* (2019)].

Numerous studies have indicated that a plant cannot benefit from the condensed forms of phosphates unless they are hydrolyzed either through biological or non-biological reactions, depending to some extent on the rate of hydrolysis of fertilizer and its potential to convert to orthophosphates, which are affected by several factors, including their interaction with aluminum, calcium and iron in the soil, as well as soil moisture, reaction and temperature [Hamilton *et al.* (2017)].

The use of the concept of kinetics is very necessary for defining the behavior of continuous interaction

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among different ions in the soil solution and the solid phase during the time and the use of thermodynamic and dynamics concepts gives a clearer and more comprehensive imaging of the process of phosphorus release in the soil, therefore, the study of the release of phosphorus from soil-added phosphate compounds and the kinetics of this release is important in the study of soil susceptibility in the providing of phosphorus.

2. Materials and Methods

Soil samples (10 g) of (0-30 cm) taken from the field belonged to the College of Agriculture,University of Anbar, had been analyzed (Table 1) based on the Black (1965). The soil sample had been mixed with 100 mg of the following fertilizers; ammonium polyphosphate (APP), di-ammonium phosphate (DAP) and mono-ammonium phosphate (MAP). Then the mixture was crushed and sieved with a 0.5 mm diameter mesh sieve. APP was locally manufactured based on Al-Khateeb *et al.* (2001). Some of the chemical and physical characteristics of the APP are shown in Table 2. Later, the mixture was placed in a plastic tube of 100 ml capacity. Orderly, 50 ml of sodium bicarbonate solution (0.5 N) was added to the tube and shacked for 5, 30, 60, 120 and 150 minutes, then 10 ml was taken from the extract to analyze available phosphate by spectrophotometer d based on Olsen (1954).

Table 1: Some chemical and physical properties of field soil used in pre-cultivated experiment.

Properties		Value	Unit
pH		7.4	——
EC		4.2	$ds.m^{-1}$
Organic matter OM		8.9	$gm.kg^{-1}$
Carbonate minerals		236	$gm.kg^{-1}$
Soluble cations	Ca^{+2}	9.8	$Mmol.l^{-1}$
	Mg^{+2}	8.4	
	Na^{+1}	12.5	
	K^{+}	25.0	
Soluble anions	SO_4^{-2}	7.6	$Mmol.l^{-1}$
	HCO_3^{-}	5.5	
	CO_3^{-}	0	
	Cl^{-}	20.0	
Available phosphorus		6.3	$mg.\ kg^{-1}$
CEC		22.10	
Soil Separaties	Sand	180	$gm.kg^{-1}$
	Silt	469	
	Clay	351	
Texture Class		SiC	

The available accumulative released phosphate concentration ($mg.kg^{-1}$) was analyzed through the first-order equation of soil phosphorus kinetics: $Ln(Co-Ct) = Ln(Co-Kt)$

where,

Ct: The released phosphorus with time t ($mg.kg^{-1}$).

Co: The concentration of phosphorus at the zero time ($mg.kg^{-1}$).

Kt: Speed coefficient of phosphorus releasing ($mg.kg^{-1}.h^{-1}$).

Physical analysis

The particle size distribution of soil separators has been estimated in the hydrometer based on Gupta (2000) (Table 2).

Soil pH and electrical conductivity (EC) were measured based on Corwin and Lesch (2003**)**. Organic matter and carbon minerals were estimated according to Pansu and Gautheyrou (2006).

Dissolved cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) were estimated according to Richards (1954). Sulfate was measured by spectrophotometer. While chloride was determined by the color method. Dissolved carbonates and bicarbonates were also estimated [Richards (1954)].

Available phosphors at a wavelength of 882 nm were measured based on Olsen (1954).

3. Results and Discussion

3.1 Studying the kinetics of phosphorus in soil

Fig. 1 shows the amount of phosphorus released (RP) according to different shake periods of APP

Table 2: Some chemical and physical properties of ammonium poly phosphate (APP) fertilizer.

Properties	APP
Solubility at 298 absolute degree	
(mg/100 ml)	25
Melting absolute degree	200
pH 10: 1fertilizer: water	7.87
ECfertilizer: water $dS.m^{-1}$	6.5
Percentage of phosphorus P%	70
Percentage of nitrogen NH_4%	21
Molecular weight Chemical structure	440 $(NH_4)_6P_4O_{13}$

fertilizer levels, the 5 minutes shake period recored the lower rate of phosphorus release at the L0 addition level of 1.84 mg $P.Kg^{-1}$ then the amount of released phosphorus began to rise as the duration of the shake increased and for all the following stages of shaking: (30, 60, 120, 150) minutes, the amount of phosphorus

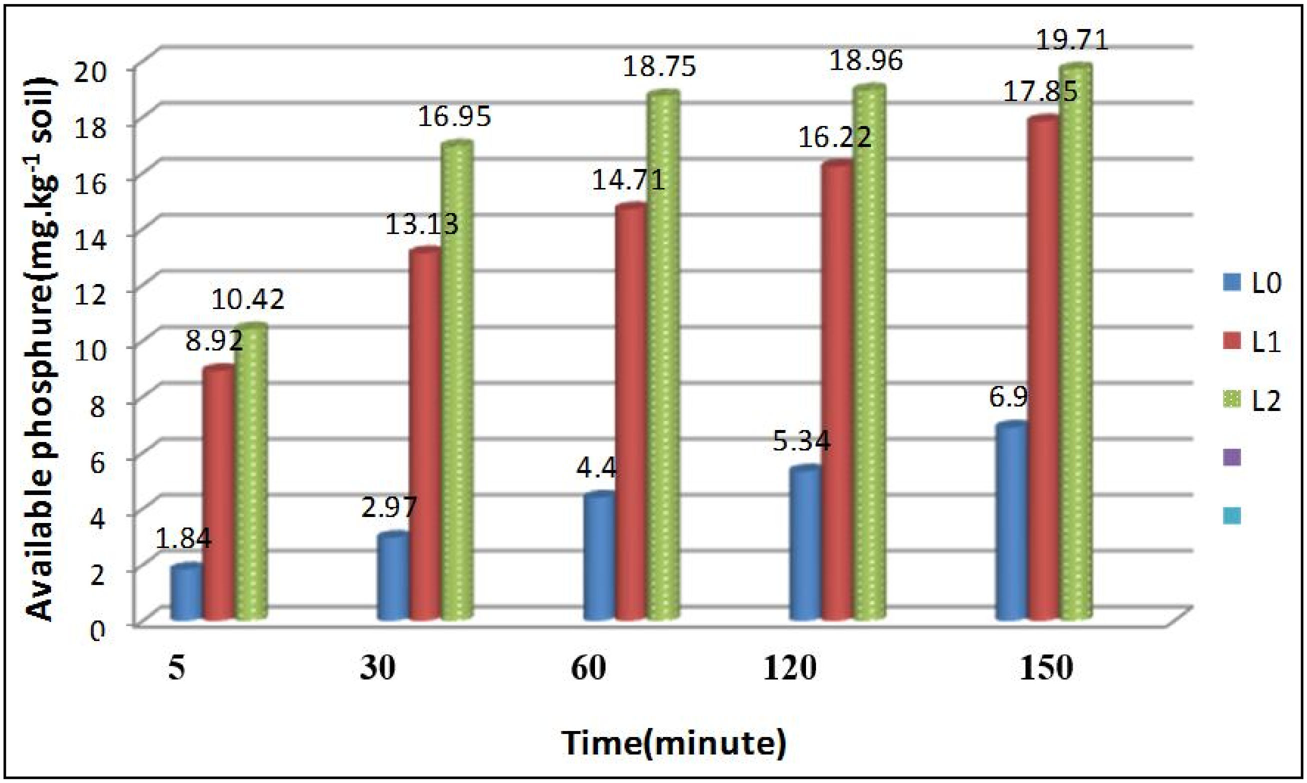

Fig. 1: Dissolved phosphorus in soil solution at several shaking periods for APP fertilizer

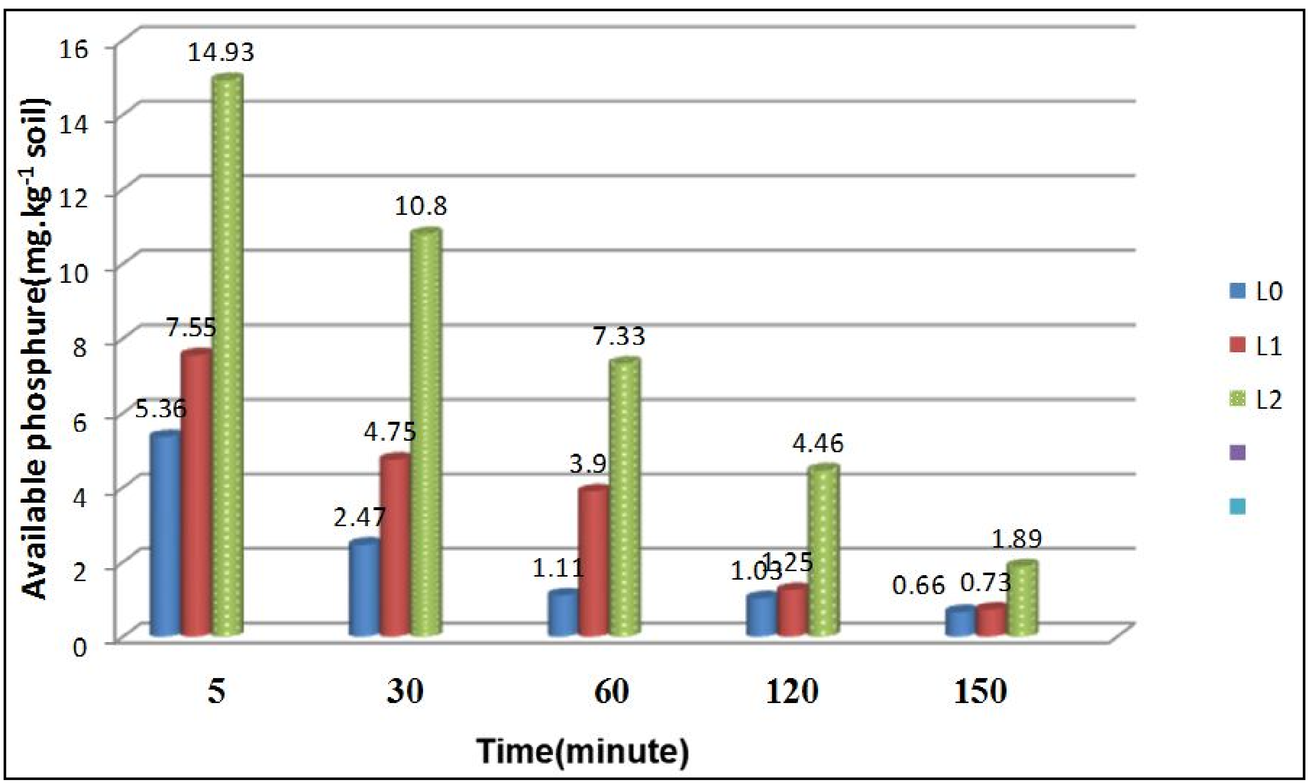

Fig. 2: Dissolved phosphorus in soil solution at several shaking periods for MAP fertilizer

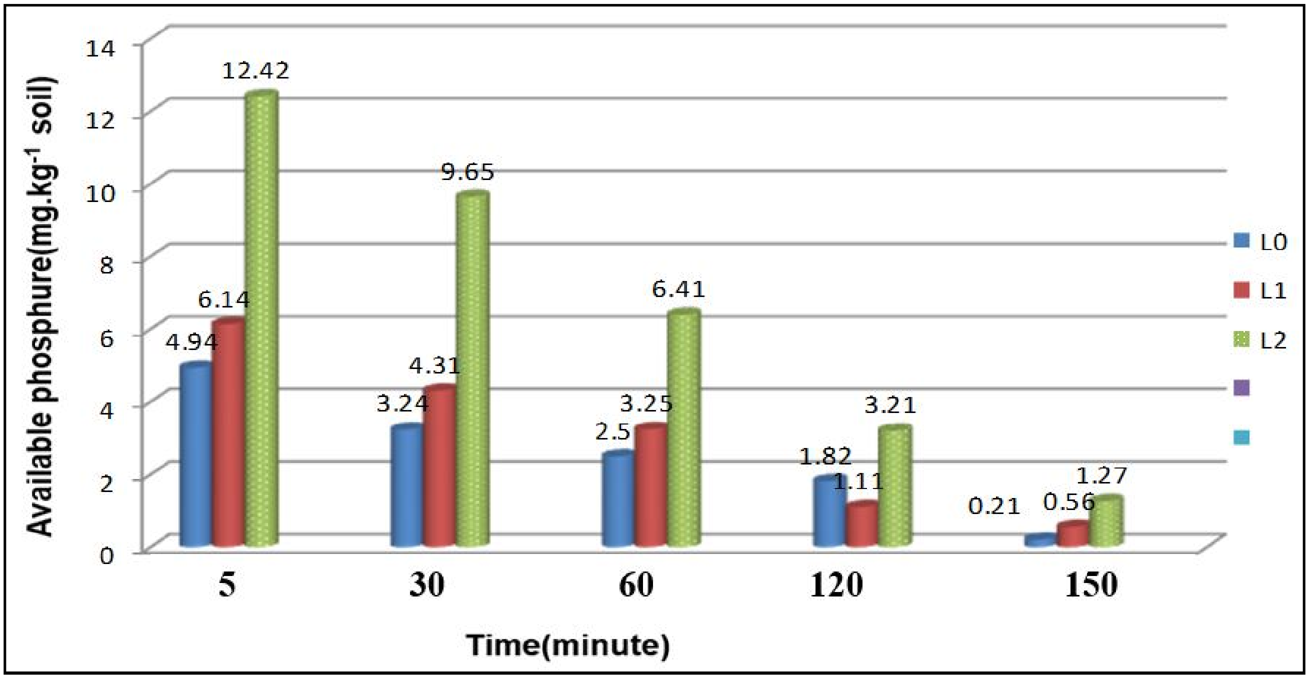

Fig. 3: Dissolved phosphorus in soil solution at several shaking periods for DAP fertilizer

released into the soil at the time of the shaking was 150 minutes and the L2 level was 19.71 mg P.Kg^{-1} soil with an increase of 90.66%.

Fig. 2 shows that the amount of RP was the highest (14.93 mg P.kg^{-1} soil) at 5 minutes SP for L2 level. The RP decreased gradually accompanying by increasing SP to reach to 0.66 mg P.kg^{-1} soil at 150 minutes SP for L0 level, *i.e.* the reduction percent was 95.57%.

Fig. 3 shows that the highest amount of RP was at the SP of 5 minutes and for L2 level at 12.42 mg P.kg^{-1} soil and then the amount of RP gradually decreased with the duration of the shaking increases, reaching 150 minutes SP and L0 level 0.21 mg P.kg^{-1} soil, which is the lowest amount with a decrease of 92.40%.

This can be attributed to the slow release of phosphorus from condensed phosphate which reduces the space of its stabilization in the soil thus it remains available longer [Joy (2003)]. In calcareous soils, the condensed phosphates cover the active sites on the calcium carbonate surface and reduce the adsorption of phosphate [Marshall and Nancalls (1969)]. While MAP and DAP traditional phosphate fertilizers are more soluble and faster to decompose from condensed phosphates, thus, we expect their quantities to increase in the first periods of shaking and then begin to decline over time as they are stabilized, deposited and dissolved. This result is consistent with McBeath *et al.* (2007) and Gao *et al.* (2020).

3.2 Coefficient of soil available phosphorus rapidity (Kd)

Table 3 show that APP source achieved significant effect compared with other fertilizer sources, as for (Kd) which recorded 3.621 mg P.kg-1.soil.minute-1 at 150 minutes SP. This result revealed that APP fertilizer is the best because it provides phosphorus to soil for a longer period. This is a positive as the providing of dissolved phosphorus in soil solution is important in plant nutrition, due to the role of condensed phosphate fertilizers in increasing RP in the soil over time, while the bulk of traditional MAP and DAP fertilizers added to the soil are converted into low-soluble calcium phosphate due to calcium ion and its effectiveness in the solution, which is consistent with Al-Hity (2007).

Table 3: Coefficient of soil available phosphorus rapidity (Kd) from several fertilization sources (mg P.kg^{-1} soil.minute^{-1}).

Source	Coefficient values (Kd)				
	Time (minutes)				
	5	30	60	120	150
APP	0.867	1.737	2.462	3.096	3.621
MAP	0.512	1.249	2.193	2.949	3.475
DAP	0.419	0.910	1.380	1.664	2.564

4. Conclusion

The addition of phosphate fertilizer with various sources affected the phosphorus availability in the soil and APP fertilizer has achieved the highest phosphorus values over time, confirming that fertilizer has slow-release properties suitable for plant growth. Therefore, it is recommended that this type of fertilizer is used as a fertilizer for the plant as a good source of phosphorus, other elements and nutrients and that it is less likely to be installed in the soil and thus provide the plant with the necessary nutrients.

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References

AL-Bayati, H.J., F.F. Ibraheem, W.B. Allela and D. K.A. AL-Taey (2019). Role of organic and chemical fertilizer on growth and yield of two cultivars of pea (pisum sativum l.). *Plant Archives,* **19(Supplement 1)**, 1249-1253.

Al-Hity, Taha Yaseen Nagris (2007). Hydrolysis study of some condensed phosphate compounds in some calcareous soils. *Ph.D Thesis*, Faculty of Agriculture, Anbar University, Iraq.

Al-Juthery, H.W.A., E.H.A.M. Ali, R.N. Al-Ubori, Q.N.M. Al-Shami and D.K.A. AL-Taey (2020). Role of foliar application of nano NPK, micro fertilizers and yeast extract on growth and yield of wheat. *Int. J. Agricult. Stat. Sci.,* **16(Supplement 1)**, 1295-1300. DocID: https://connectjournals.com/03899.2020.16.1295

Al-Khafajy R.A., AL-Taey D. K.A. and AL-Mohammed M.H.S. (2020). The impact of water quality, Bio-fertilizers and Selenium spraying on some Vegetative and Flowering growth parameters of *Calendula Officinalis* L. under Salinity stress. *Int. J. Agricult. Stat. Sci*., **16(Supplement 1)**, 1175-1180.

Al-Khateeb, I.K., S. Mohmoud, Y.A. Yosef and H. Hassan (2001). Synthesis and identification of new Polyphosphate fertilizer from phosphoric acid. *National Journal of chemistry,* **5(2)**, 203-214.

AL-Taey, D.K.A., S.S.M. AL-Azawi, M.J.H. AL-Shareefi and A.R. AL-Tawaha (2018). Effect of saline water, NPK and organic fertilizers on soil properties and growth, antioxidant enzymes in leaves and yield of lettuce (*Lactuca sativa* var. Parris Island). *Res. on Crops,* **19(3)**, 441-449. DOI: 10.31830/2348-7542.2018.0001.14

Al-Taey, D.K.A., , I J.C. AL-Naely, B.H. Kshash (2019). A study on effects of water quality, cultivars, organic and chemical fertilizers on potato (*Solanum tuberosum* L.) growth and yield to calculate the economic feasibility. *Bulgarian Journal of Agricultural Science,* **25(6)**, 1239--1245.

Black, C.A. (1965). *Methods of soil analysis*. Amer. Soc. of argon. Inc. USA.

Corwin, D.L. and S.M. Lesch (2003). Application of soil electrical conductivity to precision agriculture: Theory, Principles and Guidelines. *Agron. J.*, **95**, 455-471.

Gao, Y., X. Wang, J. Ali and G. Chu (2020). Polyphosphate fertilizers increased maize (*Zea mays* L.) P, Fe, Zn and Mn uptake by decreasing P fixation and mobilizing microelements in calcareous soil. *Journal of Soils and Sediments,* **20(1)**, 1-11.

Gupta, P.K. (2000). *Soil, plant, Water and Fertilizer Analysis.* Agrobios (India), Jodhpur, New Delhi, India.

Hamilton, J.G., D. Hilger and D. Peak (2017). Mechanisms of tripolyphosphate adsorption and hydrolysis on goethite. *J. Colloid Interface Sci.,* **491**, 190-198.

Joy, N. (2003). *Field crop Advisory Team Albert*. Michigan State University.

Krishna, G.K., T.G. Krishna, V. Munaswamy and Y.R. Ramu (2020). Distribution of inorganic phosphorus fractions and their relationship with soil properties in noncalcareous soils of chittoor district, A.P. *Int. J. Agricult. Stat. Sci.,* **16(Supplement 1)**, 1511-1517.

Mahmood, S.S., S.M. Taha, A.M. Taha and D.K.A. AL-Taey (2020). Integrated agricultural management of saline soils of Sowaira, wasit governorate. *Int. J. Agricult. Stat. Sci.,* **16(1)**, 113-119.

Marshall, R. W., and G.H. Nancollas (1969). Kinetics of crystal growth of dicalcium phosphate dihydrate. *The Journal of Physical Chemistry*, **73(11)**, 3838-3844. https://doi.org/10.1021/j100845a045

McBeath, T.M., E. Lombi, M.J. McLaughlin and E.K. Bünemann (2007). Polyphosphate-fertilizer solution stability with time, temperature and pH. *J. Plant Nutr Soil Sci.,* **170**, 387-391.

Mikkelsen, R.L. and A.B. Leytem (2005). The nature of phosphorus in calcareous soils. *Better Crops,* **89(2)**, 11-13.

Olsen, S.R. (1954). Inorganic phosphorus in alkaline and calcareous soils. *Advan. Agron.,* **4**, 84-122.

Pansu, M., and J. Gautheyrou (2006). *Handbook of Soil Analysis: Mineralogical, Organic and Inorganic Methods.* In www.springer.com. Springer-Verlag. https://www.springer.com/gp/book/9783540312109

Richards, L.A. (1954). Diagnosis and improvement of saline and alkali soils. USDA. Handbook 60 USDA Washington DC. USA. bamended soils. *Environ Qual. J.*, **34**S, 890-896.