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인산질비료 장기연용 논토양에서 유효인산 변동

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Change in Available Phosphate by Application of Phosphate Fertilizer in Long-term Fertilization Experiment for Paddy Soil

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Abstract

BACKGROUND: Phosphorus(P) is a vital factor for rice but excess input of phosphorus fertilizer can cause environmental risk and waste of fertilizer resources. We studied to assess the change of available phosphate, P balance, critical concentration of available phosphate under a rice single system.

METHODS AND RESULTS: The changes of available phosphate of paddy soil were examined from long-term fertilization experiment which was started in 1954 at the National Academy of Agricultural Science. The treatments were no phosphate fertilization(No fert., and N), phosphate fertilization(NPK, NPKC, and NPKCLS). The available phosphorus concentrations in treatments without phosphate fertilizer (No fert. and N) were decreased continuously. But, after 47 years, available phosphate content in phosphate fertilizer treatment (NPK, NPKC, and NPKCLS) reached at the highest (245~331 mg kg⁻¹), showing a tendency to decrease afterward. The mean annual P field balance in these treatments (NPK, NPKC, and NPKCLS) had positive values that varied from 16.6 to 17.5 kg ha⁻¹ year⁻¹, and ratio of residual P were increased. These showed that phosphate

fertilizer in soil were converted into the form of residual phosphorus which was not easily extracted by available phosphate extractant. Also, It was estimated that the critical value of available phosphate for rice cultivation was 120 mg kg⁻¹ using Cate-Nelson equation.

CONCLUSION: We concluded that no more phosphate fertilizer should be applied in rice single system if soil available phosphate is higher than the critical P value.

Key words: Available phosphate, Dynamics, Long-term experiment, Paddy soil

서론

(2011)
131 mg kg⁻¹ 80~120 mg kg⁻¹
(National Institute of Agricultural
Sciences, 2012).
, 가 (Sharpley,
1995). , 가 ()
(Cordell *et al.*, 2009)

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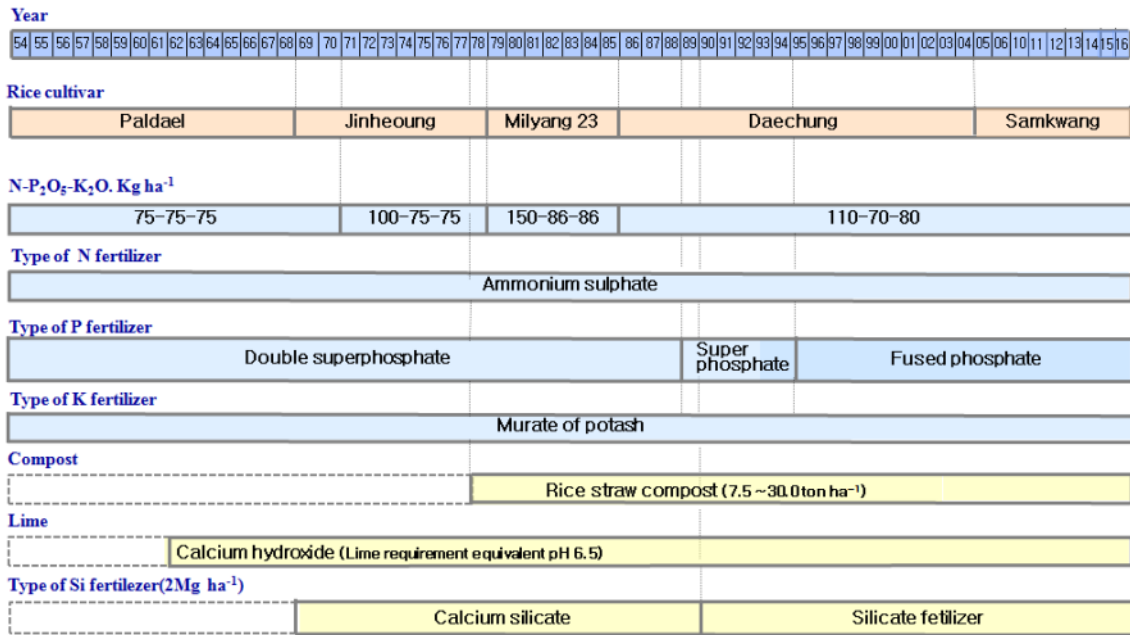


Fig. 1. Chronological application of fertilizers and rice cultivated.

-7.2~4.3 kg ha⁻¹ year⁻¹

-12.9~52.1 kg ha⁻¹ year⁻¹ (Lin *et al.*, 2006; Yan *et al.*, 2013).

27~30 kg 가

가 (Cope, 1981).

60~80% Ca-P, Al-P, Fe-P, occluded-P, residual-P pH, (Meek *et al.*, 1979), (Chang and Jackson, 1957), 가 (Reductant Fe-P) (Yoon *et al.*, 1982) stergite(FePO₄·2H₂O) , vivianite (Fe(PO₄)₂·8H₂O) 가 (Yoon *et al.*, 1982).

50% (residual-P) (Kim *et al.*, 2000) , (aging process)

가

3 (NPK), (NPKC), (NPKCLS)

1954

재료 및 방법

시험포장 토양특성 '54

100 cm

(Coarse loamy, mixed, mesic family of Anthraquic Eutrudepts) pH 5.2, (SOM) 120 mg kg⁻¹, (Av. P₂O₅) 0.08 cmol_c kg⁻¹

(NAAS, 2010)

Fig. 1

공시 품종 및 처리구 '54 '68 , '69 '78 , '79 '85 23 , '86 '03 , '04 '16

32 (No fert.), (N), 7.5 ton ha⁻¹

비료 사용량 및 재배 관리

(NAAS, 2010)
 75~150 kg ha⁻¹, 70~86 kg ha⁻¹,
 75~86 kg ha⁻¹, 7.5 kg ha⁻¹,
 ('69~'89) ('90~'14) 2 Mg ha⁻¹ ,
 pH 6.5 , - - -
 % 2 , , , ,
 50-20-20-10%, 가 70-0-30-0

3 ton

4~6 kg 가

4

5

토양 채취 및 분석

('69~'16) 4 0~15 cm
 3~7 2 mm
 '95 '15 pH
 1:5 ,
 Tyurin , Lancaster 720 nm
 , 1M NH₄OAc (pH 7.0)
 (ICP-OES, GBC)
 (National Institute of Agricultural Science and
 Technology, 2000). T-P HClO₄ ,
 P Ignition , Inorganic P Modified Chang &
 Jackson method (Kuo, 1996).

정조수량 조사 및 식물체 분석

10 70 3

40 mesh
 0.5 g 10 mL 50% HClO₄ 10
 mL 가
 (ICP-OES, GBC) (National
 Institute of Agricultural Science and Technology, 2000).

인(P) 수지

(), (),
 가 (1). No fert., N,
 NPK, NPKC, NPKCLS '69 '16
 '12
 ('69~'86) ('87~'14)
 (National Institute of Agricultural Science and Technology,
 2003) , '12
 '87 ~'14

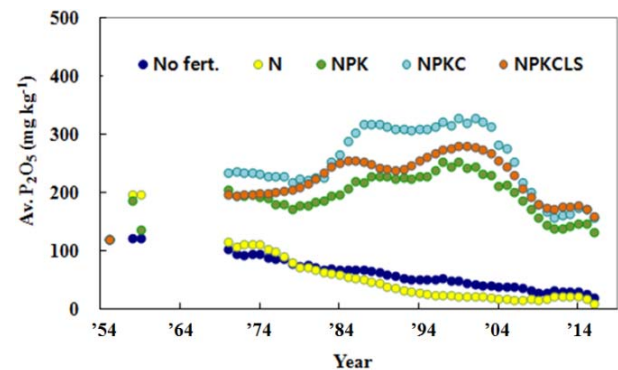


Fig 2. Change of available phosphate by continuous application of inorganic fertilizer, silicate fertilizer, lime, and rice straw compost. No fert.: No fertilization, N: Nitrogen fertilizer, NPK: nitrogen, phosphate, and potassium fertilizer, NPKC: NPK plus rice straw compost; NPKCLS: NPKC plus lime and silicate fertilizer.

Table 1. Regression equation of available phosphate according to phosphate fertilizer. No fert.: No fertilization, N: Nitrogen fertilizer, NPK: nitrogen, phosphate, and potassium fertilizer, NPKC: NPK plus rice straw compost; NPKCLS: NPKC plus lime and silicate fertilizer

Treatment	Period	Regression equation	R ²
No fert.	I ~ II ('69~'16)	y=-1.66x+97.99	0.958
N	I ~ II ('69~'16)	y=-3.35x+114.69	0.951
NPK	I ('69~'00)	y= 2.27x+174.2	0.745
	II ('01~'16)	y=-6.34x+501.43	0.809
NPKC	I ('69~'00)	y= 4.04x+210.57	0.798
	II ('01~'16)	y=-9.14x+685.15	0.724
NPKCLS	I ('69~'00)	y= 2.94x+188.79	0.895
	II ('01~'16)	y=-6.46x+556.88	0.779

Table 2. Annual P field balance in long-term fertilization experiments. No fert.: No fertilization, N: Nitrogen fertilizer, NPK: nitrogen, phosphate, and potassium fertilizer, NPKC: NPK plus rice straw compost; NPKCLS: NPKC plus lime and silicate fertilizer.

Treatment	Input (A)				Output (B)		Net balance (A-B)
	Fertilizer	Irrigation	Root and stubble	Input	rice uptake	Output	
	----- kg ha ⁻¹ year ⁻¹ -----				----- kg ha ⁻¹ year ⁻¹ -----		
No fert.	-	4.0	0.9	5.0	14.5	14.5	-9.5
N	-	2.0	1.2	3.0	18.2	18.2	-15.2
NPK	35.0	2.0	3.7	40.7	24.1	24.1	16.6
NPKC	38.5	2.0	5.0	45.5	28.6	28.6	16.9
NPKCLS	38.5	2.0	4.5	44.4	27.5	27.5	17.5

$$(P) \text{ (kg ha}^{-1} \text{ year}^{-1}) = \left(\frac{P}{P} \right) + \dots (1)$$

I, II
NPK, NPKC, NPKCLS
4.04 mg kg⁻¹, 2.94 mg kg⁻¹, 2.27 mg kg⁻¹ 가
47 245, 331, 280 mg kg⁻¹
y=2.27x+174.2y=-4.04x+210.57, y
=-2.94x+188.79

유효인산 함량과 벼 수량과의 관계

Cate-Nelson
split(Cate and Nelson, 1971)

통계 분석

(v. 9.2) t-test

SAS

II NPK, NPKC, NPKCLS
1 9.14 mg kg⁻¹, 6.46 mg kg⁻¹, 6.34 mg kg⁻¹
, '16 133, 159, 160 mg kg⁻¹
y=-1.66x+97.99, y=-3.35x+114.69
(Table 1).
, I '80 '87

결과 및 고찰

유효인산의 장기 변동

1954
120 mg kg⁻¹ No fert. N 1 1.7 ppm가 (0.01 ppm) (National Institute of Agricultural Science and Technology, 2003) 가
mg kg⁻¹ year⁻¹, 3.3 mg kg⁻¹ year⁻¹ 63
2016 19, 10 mg kg⁻¹ (Fig. 2),
y=-1.66x+97.99, y=-3.35x+114.69
(Table 1). N 가 No fert.
, N

인 수치

NPK, NPKC, NPKCLS

, N (33%)
(N, No fert.)
(NPK 59%)
50 mg kg⁻¹ 120
mg kg⁻¹ 1.66 mg kg⁻¹ 43

, No fert. N (-9.5~ -15.2 kg ha⁻¹ year⁻¹)
(Table 2).
(16.6~17.5 kg ha⁻¹ year⁻¹)
가 47

(NPK, NPKC, NPKCLS)

Fe, Ca, Al

가 ('54~'00)

('00~'16)가

('80)

Table 3. P fraction in long-term fertilization experiments. No fert.: No fertilization, **N:** Nitrogen fertilizer, **NPK:** nitrogen, phosphate, and potassium fertilizer, **NPKC:** NPK plus rice straw compost; **NPKCLS:** NPKC plus lime and silicate fertilizer

Treatment	Year	T-P	Organic-P	Residual-P	Fe-P	Reductant-P	Soluble P	Al-P	Ca-P
		mg kg ⁻¹							
No fert.	'95	205	9	119	30	10	1.8	27	8
	'15	139	8	72	37	14	1.7	22	4
t-test		**	ns	***	ns	*	ns	*	***
N	'95	224	7	170	32	13	1.2	4	2
	'15	203	7	98	53	30	1.2	8	11
t-test		**	ns	***	**	*	ns	*	***
NPK	'95	490	14	334	70	29	1.7	29	12
	'15	523	11	356	72	44	1.0	22	11
t-test		***	ns	***	ns	ns	ns	*	ns
NPKCLS	'95	470	69	275	61	5	1.2	34	25
	'15	573	47	361	67	7	2.1	24	27
t-test		***	*	***	ns	ns	*	*	ns

ha⁻¹ year⁻¹) , (54.54 kg
 (-28.76, -33.78 kg ha⁻¹ year⁻¹)
 (Shin *et al.*, 2014). , 8
 (-12.9 kg ha⁻¹ year⁻¹) ,
 (, 7,500~15,000 kg ha⁻¹)
 (3.2~52.1 kg ha⁻¹ year⁻¹) .
 (T-P) P(Residual P) 가
 No fert., N '95 '15
 , 가 NPK, NPKCLS
 가 (Table 3).

(Lancaster method)
 P
 No. fert., N, NPK '95 '15
 , NPKCLS '95 '15
 , '95 가 Fe oxide
 '15 (Change and Jackson, 1957), Fe oxide
 N Fe-P '95
 '15 가 Al-P '95 '15
 . Al
 Fe 가 Al
 . Ca-P '95 '15
 NPKCLS 가
 (Fe(PO₄)₂ Fe-P 가 .
 P(reductant P) '95 '15

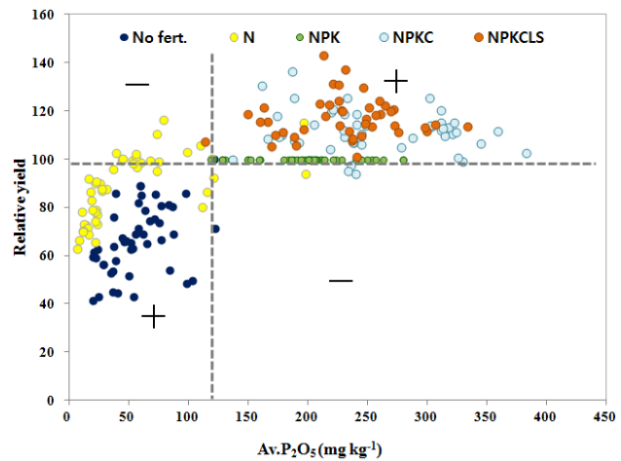


Fig. 3. Relationship relative grain yield and the content of available P₂O₅ in long-term experiments No fert.: No fertilization, **N:** Nitrogen fertilizer, **NPK:** nitrogen, phosphate, and potassium fertilizer, **NPKC:** NPK plus rice straw compost; **NPKCLS:** NPKC plus lime and silicate fertilizer.

가 Fe oxide
 (Change and Jackson, 1957), Fe oxide
 Al-P '95 '15
 . Al
 Fe 가 Al
 . Ca-P '95 '15
 NPKCLS 가

토양의 유효인산의 한계농도

120 mg kg⁻¹ (Fig. 3).
(80~120 mg kg⁻¹)
(National Institute of Agricultural
Sciences, 2010).

결 론

63
120
mg kg⁻¹ 47 245~331 mg kg⁻¹
가 , 48 133~160
mg kg⁻¹
16.6~17.5 kg ha⁻¹ year⁻¹
가
가
Cate-Nelson
120 mg kg⁻¹ 가
(80~120 mg kg⁻¹)가

Notes

The author declare no conflict of interest.

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