

Studies with P³² Tracer on Laboratory Index of Available Phosphorus in Paddy Soil, Korea (II)

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P³² 追跡子法에 의한 土壤의 有効 磷酸定量法에 관한 研究 (II)

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要 約

韓國畚土壤十種을 試料로하여 有効磷酸定量에 적합한 化學的 抽出方法을 찾고져 A-value (磷-32 追跡子法에 의한 有効磷酸定量值)를 표준으로 하여 시험한 결과 다음과 같은 結果를 얻었다.

1. A-value 는 Fe-P(磷酸鐵)와만 1%水準의 有意相關이 있으므로 畚土壤의 有効磷酸은 Fe-P 系에 의하여 支配되고 있다고 볼 수 있다.
2. 本 實驗에 使用한 6個浸出法은 Fe-P 와 相關이 없으므로 畚土壤有効磷酸定量法으로 적합하지 않다.
3. 畚土壤有効磷酸에 적합한 浸出法은 Fe-P 系의 還元強度를 測定할 수 있는 것이어야 하며 浸出強度는 平均 270 ppm 으로 推定된다.
4. Bray No. 2-p 는 Lancaster-p, Spurway-p, Truog-p 및 (Ca+Al)-p 와 5% 水準 以上에서 有意相關이 있고 Al-p 는 Olsen-p 및 Lancaster-p 와, Ca-p 는 Spurway-p 와 1% 水準에서 有意相關이 있다.

The application of adequate amount of phosphate fertilizer to paddy soil may be essential rather for maintaining balance between the nutrients of rice plant than by economic reasons. According to the simple experiments²⁴⁾ on three major elements carried out at farm fields the increase in amount of phosphorus often caused a fall in grain yield providing the levels of nitrogen and potassium are the same. The reason may be attributed to the unbalanced fertilization.

Olson et al¹⁷⁾. reported that an excessive dose of phosphate invited a depression of yield in the culture of soybean and sorgham. Lee et al¹¹⁾. related a harmful effect of excessive phosphate to some action on nucleic acids. With the culture of paddy rice, however, little information is available on the unfavorable effect of phosphorus. Noggle¹⁴⁾ reasoned that the excessive uptake of phosphorus might cause the increase of inorganic anions against cations and hence the relative decrease in organic

anions resulting low grain yeild. Place et al.¹⁸⁾ described on the lodging of rice plant caused by an excessive dose of phosphorus.

The estimation of right amount of phosphorus to be applied to paddy soil may be attained by field trial (for three elements) but only by approximation because of the residual reaction. The detailed scale suitable for all individual fields may not be expected. The determination is to be based on the balance of available phosphorus in soil and the phosphorus should be simply measured by chemical extraction. Vernon et al.²²⁾ refrained from applying phosphorus to some soils based on the determination.

The authors already presented a paper describing the estimation of phosphorus absorbable to rice plant by the use of P-32 and the change in amount of absorbable phosphorus with time and the moisture conditions preparatory to the search for a suitable method for chemical extraction of available phosphorus

horus. Following this preliminary work the comparison of the conventional methods for estimating available phosphorus with special reference to their dependability has been performed employing the tracer method as the standard.

MATERIAL AND METHODS

Ten soil samples including a volcanic ash and a reclaimed soil as described in the previous report¹⁰⁾ were employed and analyzed for the available phosphorus using six extraction methods as tabu-

ated in Table I. The quantitative fraction of Ca-P, Fe-P, and Al-P also was carried out for each sample after the Jackson's procedure.⁹⁾ The resulting values were recalculated as the amount of available phosphorus (P_2O_5) kg per ha regarding the dry weight of soil per ha as 2×10^6 kg.

The determination of available phosphorus by the tracer method was performed with the materials of 4th week¹⁰⁾ after transplanting and the values were compared with those from the extraction and the fractionation.

Table I. Methods of Available Phosphorus Determination

Method	Extractant	pH	Soil: solution ratio	Shaking time (minutes)	Color developed
1. Bray No. 1	0.052N-HCl +0.03N-NH ₄ F		1 : 10	5	Ammonium molybdate stannous chloride in HCl medium
2. Bray No. 2	0.1N-HCl +0.03N-NH ₄ F		"	"	"
3. Lancaster	20L. Solution containing 400cc. conc. acetic acid 300cc. 10N-lactic acid 22.2 gm NH ₄ F 133.3gm (NH ₄) ₂ SO ₄ , 170gm NaOH	4.25±0.05	1 : 4	10	Ammonium molybdate-1-amino-2 naphthol-4-sulfonic acid
4. Olsen	0.5N-NaHCO ₃	8.5	1 : 20	30	Ammonium molybdate stannous chloride in HCl medium
5. Spurway	0.13N-HCl		1 : 10	5	"
6. Truog	0.002N-H ₂ SO ₄	3.0	1 : 20	30	Ammonium molybdate stannous chloride in H ₂ SO ₄ medium

RESULTS AND DISCUSSION

The values of, "available" phosphorus determined by various extraction methods, of phosphorus fractions, and A values, of the soil samples under study are presented in Table II.

All of the values obtained from the same soil are significantly different at 5% and 1% levels. The mean values were in the order of A-value > Ca-P > Fe-P > Al-P > Br. No. 2-P > Spurway-P > Lancaster-P > Olsen-P > Br. No. 1-P. This results may suggest that any one of those from the fractional and extraction methods does not represent "true" available phosphorus but two or more combinations may present a possibility of transformation of unavailable to available ones.

The reaction of soils under investigation covers the range of 5.2 to 6.5 in pH. Over this range there were significant correlations among pH, Fe-P, and A-value with the values of 0.745 and 0.694 respectively at 5% level. However, no correlation was found with the results from the extraction methods. Such a positive correlation between pH, Fe-P, and A-value was more apparent as pH increased being quite opposite to Al-Abbas et al's¹⁾ results. As shown in Fig. 1 in the state below pH 6 Fe-P is considered to be the major part of P followed by Al-P and Ca-P. This results are in accordance with those by Al-Abbas¹⁾ and Synn et al.¹⁹⁾

The analysis of correlation between A values and the values from the extraction and fractionation methods are shown in Table III.

Table II. Various Phosphorus in Soils and Correlation Analyses between them (P₂O₅ kg/ha)

Soil	Phosphorus	A-value and others	Br-1	Br-2	Lan.	Olsen	Spurway	Truog	Ca-P	Al-P	Fe-P	Fe+Olsen	Ca+Al-P	Ca+Fe-P	Al+Fe+Ca
			"	"	"	"	"	"	"	"	"	"	"	"	"
1	548	48	144	88	100	54	32	184	292	418	518	476	602	710	894
2	839	38	156	98	122	64	38	336	358	778	900	694	1114	1136	1472
3	295	36	134	82	78	122	40	386	234	174	252	620	560	408	794
4	514	34	208	94	76	424	36	1248	308	312	388	1556	1560	620	1868
5	465	92	318	192	106	136	78	258	434	266	372	692	524	700	958
6	574	14	70	34	504	40	54	166	166	358	408	332	524	524	690
7	525	28	112	64	84	46	34	170	252	280	364	422	450	532	702
8	582	36	148	66	100	46	32	182	336	700	800	518	882	1036	1218
9	453	48	368	110	68	550	98	1090	250	140	208	1340	1230	390	1480
10	629	20	92	50	94	38	34	174	240	618	712	414	192	858	1032
mean	542.4	39.4	175.0	87.8	87.8	152.0	47.6	419.9	287.0	404.4	492.2	706.4	823.8	691.4	110.8
LSD 5%	140.7	29.6	97.9	43.5	21.0	184.1	23.0	408.2	76.6	223.7	237.5	416.1	374.1	255.3	394.7
LSD 1%	202.3	42.6	140.7	62.5	30.2	264.8	33.0	587.0	110.2	321.7	341.6	598.4	538.0	367.1	567.5

Table III. Correlation Analyses Between Phosphorus

A-value and others	--	-0.012	-0.292	-0.206	0.507	-0.034	-0.314	-0.220
Br-1	//	--	--	0.476	0.724*	0.507	0.148	0.055
Br-2	//	--	--	--	0.803**	0.062	0.757*	0.605
Lan.	//	--	--	--	--	0.420	0.328	0.232
Olsen	//	--	--	--	--	--	-0.322	-0.286
Spurway	//	--	--	--	--	--	--	0.616
Truog	//	--	--	--	--	--	--	0.957**
Ca-P	//	--	--	--	--	--	--	--
Al-P	//	--	--	--	--	--	--	--
Fe-P	//	--	--	--	--	--	--	--
Fe+Olsen	//	--	--	--	--	--	--	--
Ca+Al-P	//	--	--	--	--	--	--	--
Ca+Fe-P	//	--	--	--	--	--	--	--
Al+Fe-P	//	--	--	--	--	--	--	--
and Fe+Ca+Al-P								
A-value and others	0.212	0.850**	0.845**	-0.199	0.243	0.809**	0.270	
Br-1	//	0.582	-0.192	-0.152	0.094	-0.055	0.061	
Br-2	//	0.495	-0.440	-0.413	0.658	0.397	-0.237	
Lan.	//	0.802**	-0.287	-0.233	0.375	0.080	-0.010	
Olsen	//	0.786**	0.630	0.682*	-0.182	0.014	0.788**	
Spurway	//	0.007	-0.531	-0.599	0.940**	0.727*	-0.463	
Truog	//	0.102	-0.544	-0.536	0.408	0.108	-0.446	
Ca-p	//	0.010	-0.420	-0.425	0.982**	0.840**	-0.365	
Al-p	//	--	0.269	0.323	0.614	0.172	0.536	
Fe-p	//	--	--	0.997**	-0.363	0.139	0.957**	
Fe+Olsen	//	--	--	--	-0.358	0.133	0.971**	
Ca+Al-p	//	--	--	--	--	0.856**	-0.259	
Ca+Fe-p	//	--	--	--	--	--	0.174	
Al+Fe-p	//	--	--	--	--	--	--	
and Fe+Ca+Al-p							0.269	

* Significant at 5% level.

** Significant at 1% level.

Between A value and the values from the extraction methods except that of Olsen-P there was a negative correlation and even in the value of Olsen-P, although in positive correlation, no significance was observed. Olsen¹⁶⁾ found a highly significant correlation between A-value and water-soluble phosphorus and Ames²⁾ found a high correlation ($r=0.95$) between A-value and the value from the resin treatment. All of these findings were, however, relevant to the upland soils. In case of the paddy soils, according to Chiang⁶⁾ and Kerezting⁹⁾, the extraction methods were not suitable compared to the seedling method.

There was found a significant correlation between A-value and Fe-P, that is, $r=0.850$ at 1% level. As mentioned above A-value is composed not only of Fe-P but possibly also of one or more other forms. When the sum of values from various methods in various ways was correlated to A-values, Fe-P+Olsen-P and Al+Fe-P indicate a significant correlation at 1% level but the coefficients are less than that with Fe-P. This implies that the participation of Al-P, if any, may be slight.

Paddy soils are usually at the acidic side and pH of the present soils under test is mostly below 6. Accordingly the fixation of phosphorus may be performed through the pathway $\text{Ca-P} \rightarrow \text{Al-P} \rightarrow \text{Fe-P} \rightarrow \text{Occluded-P}$,^{3,4,5,20,25)} Fe-P being dominant in amount. Fe-P may be transformed into soluble Fe^{2+} -P,^{7,13)} by reduction under a submerged condition while insoluble Al-P or Fe-P may be rendered soluble in a form of mineral-organic complex by virtue of organic matter.

Tyner et al.²¹⁾ described that the size and reactivity of Fe-P system greatly affect the availability of phosphorus. Recently Al-Abbas et al.¹⁾ found the method they employed ($\text{NaOH-Na}_2\text{C}_2\text{O}_4$ extraction) to be highly correlated with A-value and attributed the findings to the fact that the method mainly determines Fe-P fraction.

In the light of the above references together with the correlation analysis of present study the available phosphorus in the soils under investigation also are considered to be composed dominantly of Fe-P fraction.

In most of the soil samples studied Fe-P was found to be the dominant inorganic phosphorus fraction. In Korea most of paddy soils contain much more Fe-P than other forms of phosphorus except neomarine alluvial soil in which Ca-P dominates over Fe-P. When the readily reducible Fe is included in Fe-P, Fe-P will be the predominant inorganic phosphorus fraction in most of soils in Korea.¹⁹⁾ Therefore the available phosphorus in paddy soils in Korea may be regarded to belong to the Fe-P system. However, more detailed study will be necessary to apply this principle to Korean soils in general.

In the paddy soils in which the effect of the added phosphorus is meager¹⁵⁾ the cause may be due to the increase of available phosphorus in amount through the reduction of Fe-P as above mentioned. The determination of proper amount of phosphorus shall be performed through "critical value" based on the intensity of reductive transformation and yield tests.

It was observed as shown in Table II that all of six extraction procedures failed to indicate a correlation with Fe-P and that the methods were inadequate to determine the amount of the available phosphorus in the soils, requiring any other means to develop. However, according to Fig. 2 where the relationship between A-value and Fe-P was indicated one may be able to find out the conditions in the extraction of available phosphorus in paddy soils. In the equation, $P_A = 326.2 + 0.535P_{Fe}$, where the relation of A-value and Fe-P was formulated, if $P_{Fe}=0$, P_A equals 326.2. This means that there might be the pool of available phosphorus amounting 326.2kg/ha equivalent to 163 ppm per g of dry soil. Accordingly the intensity of available phosphorus in the extract is to be over at least 163 ppm and the mean value 271 ppm, that of A-value, where a significant correlation with Fe-P must exist.

The average value of available phosphorus under the condition excluding Fe-P, 326.2kg/ha, is far surpassing the amount of uptake by rice plant (40 kg/ha). So, if the amount of available phosphorus that affects the yield of rice be below 326.2 kg/ha Fe-P shall be in the range of "luxury consumption"

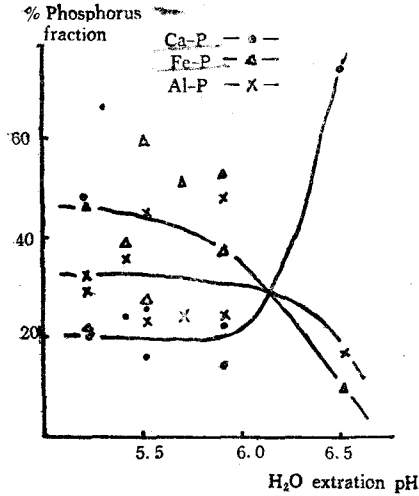


Fig. 1. Relationship between soil pH and percentage of inorganic P fractions

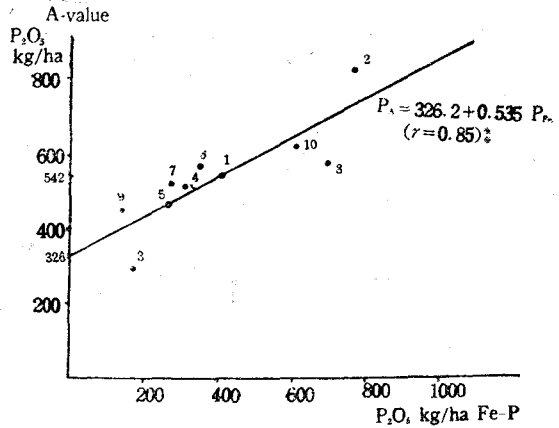


Fig. 2. Correlation between A-value and iron phosphate

or of excessive uptake which might be harmful to the plant. The application of phosphorus in such a paddy soil is useless.

Correlation between the amount of available phosphorus determined by extraction method and that of each inorganic phosphorus fraction is shown in Fig. 3. Bray No. 2-P showed highly significant correlation with Truog-P indicating $r=0.828$ and a significant correlation with Lancaster-P, Spurway-P, and (Ca+Al)-P. The results are somewhat similar to those reported by UNKSOF²³) in which

Bray No. 2-P showed highly significant correlation with Lancaster-P, Spurway-P, Bray-No. 1, and Olsen-P. Bray No. 2-P may include much of (Ca+Al)-P. Lancaster-P and Olsen-P include much of Al-P as shown in Fig. 4 and Spurway-P appears to include only Ca-P as indicated in Fig. 5 ($r=0.957$ with Ca-P).

The amount of organic matter in the samples under study was low enough to ignore in the consideration but the relationship between Fe-P and organic phosphorus should be further investigated.

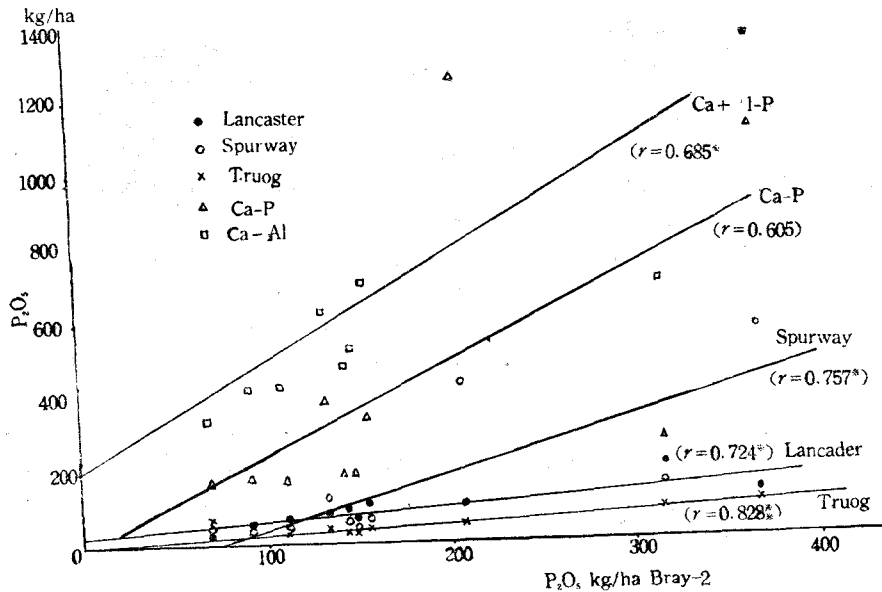


Fig. 3. Relationship between Bray No. 2-P and other phosphates

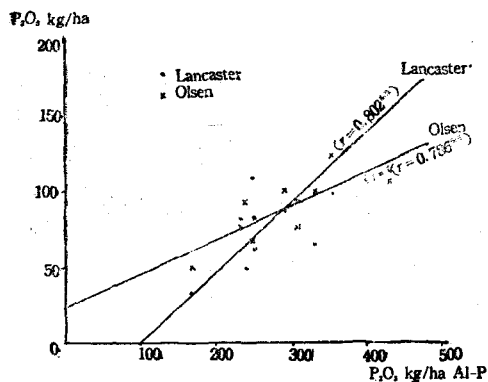


Fig. 4. Correlation between Al-P and Lan-P or Olsen

The present work revealed that the available phosphorus of paddy soils in Korea was mainly composed of Fe-P and suggests that the survey of Fe-P for much more samples and the measure of determining the deficiency of Fe-P and activity (reductive transformation) is to be further developed.

SUMMARY

The present study has been undertaken to see if any proper measure be found for the determination of available phosphorus by chemical extraction on the basis of A-values as the standard. The results obtained are described as follows.

1. Since A-value of the samples under study showed a significant correlation with Fe-P at 1% level. The available phosphorus in the present paddy soils was considered to be affected by Fe-P.
2. Six methods for chemical extraction were not correlated with the determination of Fe-P, proving them inadequate for the quantitative measurement of available phosphorus.
3. Adequate method for extracting available phosphorus in paddy soils should rest on the measurement of the reduction intensity of Fe-P. The extractable intensity was estimated to be 270 ppm in average.
4. Bray No. 2-P showed significant correlation with Lancaster-P, Spurway-P, Truog-P, and (Ca+Al)-P at 5% level. Olsen-P and Lancaster-P indicated significant correlation with Al-P and Spurway-P with Ca-P respectively at 1%

level.

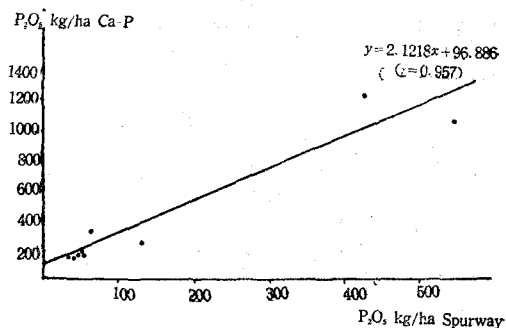


Fig. 5. Correlation between Ca-P and Spurway-P

level.

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