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^{32}P 间接标记法评价直接使用磷矿粉的有效性

AVAILABILITY OF PHOSPHORUS FROM GROUND PHOSPHATE ROCKS FOR RAPE (*Brassica napus* L.)

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^{32}P 间接标记法评价直接使用磷矿粉的有效性*

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摘　要

应用^{32}P标记过磷酸钙间接标记磷矿粉的方法，在盆栽条件下，用酸性土壤种植油菜，研究中国贵州磷矿粉对油菜的有效性。结果表明，使用磷矿粉可以使油菜获得显著的增产效果。并且用A值法测出磷矿粉中磷的有效性相当于过磷酸钙中磷的有效性的17.1%，并推算出1 kg过磷酸钙的肥效相当于8.53 kg贵州磷矿粉的肥效。同时，田间小区试验结果表明，贵州磷矿粉和浏阳磷矿粉主要是通过使油菜角果数显著增加而使油菜获得很好的增产效果的，其肥效试验结果与盆栽试验结果相同。

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Availability of Phosphorus from Ground Phosphate Rocks for Rape (*Brassica napus* L.)*

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ABSTRACT

The availability of phosphorus from the ground phosphate rock, which is provided by Kaiyang mining plant, Guizhou Province of China, is investigated in pot experiment with acid red soil for rape (*Brassica napus* L. No. 13 Xiangyou, Chinese Olive Group) by ^{32}P indirect labelling method. The results show that the yield increased significantly by applying ground phosphate rock (GPR) and the efficiency of GPR is equal to 17.1% of that from calcium superphosphate. It is calculated as that the fertilizer efficiency of 1 kg of calcium superphosphate is the same as that of 8.53 kg ground phosphate rock in Guizhou Province of China. The effect on the grain yield is evaluated by pot and field microplot experiments, and it is found that the main effect is to increase the pod number. The fertillzer efficiency in field experiment is the same as that in pot experiment. (9 refs, 1 fig, 7 tabs)

* The Project Supported by the Internation Atomic Energy Agency (IAEA) Research Contracts.

INTRODUCTION

There is a great deal of ground phosphate rocks (GPRs) in China but 86% of the GPRs contains phosphorus (P_2O_5) is lower than 25%[1] and not available for industrial production. However, the GPRs can be used directly as phosphate fertilizer with easy processing, low cost and good fertilizer effectiveness. According to the preliminary research the fertilizer effectiveness of GPRs applied directly to acid soil is regarded as positive and varies with characteristics of GPRs, soil and plant [2~4]. Because the effectiveness is not as stable as that of chemical fertilizer in the first year and the theoretical explanation and systematic applying techniques are not available, the GPRs have not been used directly as phosphate fertilizer in large scale. It is very important to know the optimum amount of the GPRs applied upon the commercial and environmental view, especially for the developing countries.

The research project is financially supported by the International Atomic Energy Agency (IAEA) and commenced at November 1, 1994. ^{32}P indirect tracer technique [5~7] is used in the experiment to evaluate the availability of phosphorus from the Chinese ground phosphate rocks, which is used as a cheap phosphate fertilizer, for rape (*Brassica napus* L.). The pot and field microplot experiments are conducted in Hunan province under subtropical conditions.

1 MATERIALS AND METHODS

1.1 Soil and Ground Phosphate Rocks

The acid red soil is used in the experiment and its agrochemical characters are shown in Table 1.

Table 1 Agrochemical characters of the acid red soil

	pH	Organic Matter %	Total N %	Total P %	Total K %	Avail. N mg/kg	Avail. P mg/kg	Avail. K mg/kg
Pot	6.1	2.52	0.233	0.200	1.40	164.7	7.27	113.3
Field	5.5	1.88	0.146			100.4	5.00	113.2

The ground phosphate rock used in the experiment No. 1 was taken from Liuyang, Hunan province, and others from Kaiyang, Guizhou province. The available P (P_2O_5%) and total P (P_2O_5%) of the GPRs are shown in Table 2. The GPRs were smashed to smaller pieces with the size of ϕ 0.25 mm. The calcium superphosphate contains 10.28% and 12.78% of available P (P_2O_5%) and total P (P_2O_5%) respectively.

Table 2 Characters of the ground phosphate rocks

Type No.	Origin	Available P (P_2O_5) %	Total P (P_2O_5) %
No. 1	Liuyang, Hunan	4.58	24.17
No. 2	Kaiyang, Guizhou	6.81	32.50

1.2 Treatments and Replications

1.2.1 Field Experiment

Five treatments with three replications and random arrangement were designed for the field experiment. Treatment 1, absent of phosphate fertilizer, was designed as control (CK). Others were as follows: treatment 2 applying $Ca(H_2PO_4)_2$ with available P (P_2O_5) of 75 kg/hm^2; treatment 3 applying the GPR No. 1 with available P (P_2O_5) of 75 kg/hm^2; treatment 4 applying the GPR No. 2 with available P (P_2O_5) of 75 kg/hm^2 and treatment 5 applying the GPR No. 2 with available P (P_2O_5) of 150 kg/hm^2.

The fertilizer rate of N/P/K applied was 1/0.5/0.5, i. e. 150 kg N, 75 kg P_2O_5, 75 kg K_2O. The 1/3 of N plus the total P and K was applied as base fertilizer, the other 2/3 of N as top dressing. Each microplot had an area of 20 m^2. The rape (*Brassica napus* L.) used in this experiment was Xiangyou No. 13 (Chinese Olive Group) sown on September 26, 1994. 240 individuals were transplanted to microplots on November 7. 1994 and harvested on May 8, 1995. The grain yield and oil content of the rape were determined.

1.2.2 Pot Experiment

The pots with 25 mm in diameter and 30 mm in height were used and each with 10 kg of acid red soil. 6 treatments with 3 replications were designed as follows: treatment 1 (CK1), absent of phosphate fertilizer, treatment 2 (CK2), applying 3.2 g of ^{32}P-calcium superphosphate mixed up with soil, treatment 3, 4, 5 and 6, each mixed up with CK2 respectively, then plus the GPR No. 2 with P_2O_5 of 330 mg/pot, 660 mg/pot, 990 mg/pot and 1320 mg/pot respectively. The fertilizer rate of N/P/K was 1/0.5/0.5. The rape was sown on September 26, 1994 and was transplanted into pot on November 24, 1994 (one individual with one pot). The radioactivity of ^{32}P in each pot was 37 MBq.

The sampling was made at seedling-stage (December 21, 1994), bolt-forming stage (February 17, 1995), flowering stage (March 16, 1995) and mature stage respectively. The rape was sampled at different vegetation stage and the samples were divided into root, stem or flower or seed respectively after being washed with

water, then stoved at 80 ℃ and weighted. The radioactivity of ^{32}P of each part from sample was determined by relative standard, total P by colorimetric analysis and the oil content by remains. All the data got from the experiment were statistically analyzed.

1.2.3 Calculation

By using ^{32}P indirect labeling tracer techniques the availability of phosphorus from the GPRs for rape (*Brassica napus* L.) was evaluated by "*A*" value as follows.

$$A=\frac{\text{PDFS}\%}{\text{FDFF}\%}\times\text{Applied fertilizer (mg } P_2O_5\text{/pot)}$$

$$\text{PDFF}\%=\frac{\text{Radioactivity of } ^{32}\text{P in plant sample}}{\text{Radioactivity of } ^{32}\text{P in fertilizer}}\times 100$$

$$\text{PDFS}\%=1-\text{PDFF}$$

2 RESULTS

2.1 Pot Experiment

2.1.1 Biological Effect of the GPRs on Rape (*Brassica napus* L.)

As shown in Table 3, a promote effect of the GPRs on the growth and development of the rape is found in the pot experiment. The dry weight of the rape treated with the GPRs in different growth period is obvious higher than that of control absent of phosphate fertilizer. The effect of the grain yield increase is also significant, 2 times higher than that of control and equal to that of treatment 1. The commercial characteristics of the rape such as the pod number of plant, seed number per pod and the seed mass per 1000 grains also increased by applying the GPRs.

Table 3 Effect of the GPRs on the production and commercial characteristics of rape

Treatment	Pod number of plant	Seed number pod	Mass of 1000 grains g	Grain yield g/pot	Increasing rate %
1 (CK1)	162	12.5	2.65	5.35	100
2 (CK2)	182	19.8	3.0	10.97	205.0
3	181	17.6	3.45	11.00	205.6
4	178	20.7	2.85	10.51	196.4
5	191	18.3	2.95	10.30	192.5
6	189	12.4	3.45	8.05	150.5

2.1.2 The uptake, distribution and utilization of phosphorus by the rape (*Brassica napus* L.)

The dynamic curve in Figure 1 shows the uptake of phosphorus by rape in different vegetation period. It indicates that the uptake of phosphorus from fertilizer by rape in the earlier stage is higher than that from soil, and the phorphorus from soil increased with the growth and development of the rape. The uptake from calcium superphosphate in seedling stage is lower than that from GPRs. There is a peak for phosphorus uptake from fertilizer during the period from the seedling stage to the bolt-forming stage and the uptake rate (0.272 mg/d) is about 71.4% of the total during the vegetation period.

After the bolt-forming stage the phosphorus uptake from fertilizer decreased and phosphorus in plant increased by only 8.3 mg and the total phosphorus was from 31.93 mg to 109.4 mg because the phosphorus absorbed by rape was mainly from soil at this stage. The distribution of phosphorus in plant varied with the growth and development of the rape. Before the boltforming stage, about 80% of the total phosphorus accumulated in the stem and at flowering stage it transferred to the breeding organs to meet the demand for the phosphorus during pods and seed development. At mature stage phosphorus in seed is about 83% of the total in plant. Table 4 shows that from the flowering stage to mature stage the phosphorus accumulation is about half of the total during the whole vegetation period, indicating that it is a very important period for rape to uptake the phosphorus.

2.1.3 Availability of phosphorus from the GPRs

A-value determination result in this experiment is shown in Table 5. The availability of phosphorus from the GPRs is evaluated by the A-value of the 3 treatments with the GPRs minus the A-value of the treatment 1 (CK1) respectively. It is found from the table that A-value of each treatment group varies with different growth stages. As A-values of the 3 treatments with the GPRs are very close in the mature stage, it indicates that the availability of phosphorus from the GPRs do not vary much with the amount applied to the field. For example in treatment 2 with GPRs of 330 mg P_2O_5, A-value (A2-A1) of 56.5 mg P_2O_5 is obtained. It means that the availability of phosphorus from the GPRs is about 17.1% of that from the calcium superphosphate. As the available phosphorus (P_2O_5) of the GPR and calcium superphosphate is 6.81% and 10.21% respectively, the equivalent relation can be shown as

$$5.65/0.0681 = x/0.1021 \qquad x = 8.53$$

The is to say that the fertilizer efficiency of 8.53 kg of the GPR from Kaiyang Guizhou province is equal to that of 1 kg of the calcium superphosphate.

Table 4 Uptake, distribution and utilization of phosphorus by the rape

	mg/pot	Uptake rate %	Fertilizer-P dynamic rate %	Root %	Stem %	Distrbution flower %	Seed %	Total-P mg/plant
Seedling stage	4.77	1.17	0.177	10.8	89.2	—	—	7.53
Bolt-forming stage	20.55	5.02	0.272	19.6	80.4	—	—	31.93
Flowering stage	25.53	6.24	0.184	9.4	61.1	7.5	—	58.61
Mature stage	28.71	7.03	0.06	3.8	12.9	—	83.3	109.40

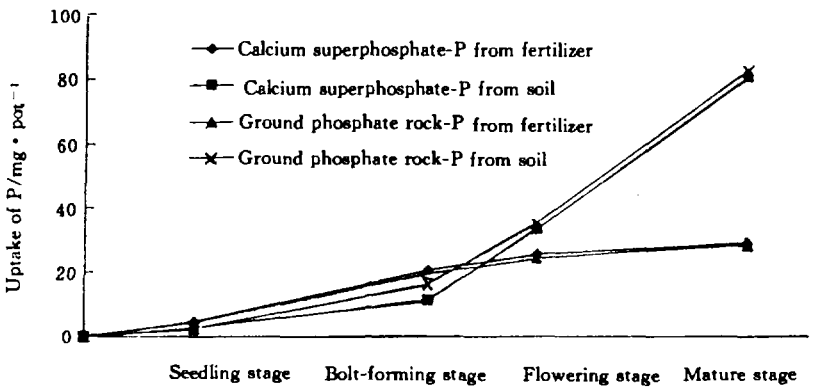

Fig. 1 Uptake of phosphorus by rape during vegetation period

Table 5 A-value of the rape (*Brassica napus* L.) at different growth stages/ (mg • pot^{-1})

Treatment	Bolt-forming stage		Flowering stage		Mature stage	
	A-value	Remain	A-value	Remain	A-value	Remain
1	226.5	0	529.9	0	1146.0	0
2	344.9	118.4	584.2	54.3	1202.5	56.5
3	219.6	−6.9	665.3	135.4	1194.9	48.9
4	326.7	100.2	801.4	271.5	1211.4	65.4
5	343.0	116.5	1009.2	479.3	1015.1	−132.9

2.2 Field Experiment

It is obvious that the effect of the GPRs on promoting the growth and development of the rape (*Brassica napus* L.) under field conditions is the same as that under pot conditions. After 45 days the transplanted rape plant in treatment 1 had 4.8 leaves and that in other treatments with phosphate fertilizer had more than 6 leaves. Table 6 shows that the yield of treatment 1, 2, and 3 with the GPRs increases significantly, about 1.6 to 1.8 times higher than that of control. Under the experimental conditions the efficienly of GPRs is better than that of calcium super-

phosphate. The yield of rape with application of the GPR from Liuyang Hunan province increased by 27.61% compared with that of applying calcium superphosphate and the difference is significant. The result is similar to that reported by Mr. CHEN Shaosan who conducted the experiment in Hubei Province [8,9]. The same commercial characters is obtained as that in pot experiment by applying the GPRs.

Table 6 Effect of the GPRs on the commercial characters of rape (*Brassica napus* L.)

Treatment	Pod number per plant	Seed number per pod	Mass of 1000 grains g	Oil content %	Grain yield g/microplot	Increasing rate %
1	145	22	2.31	41.49	850	100
2	283	20	2.49	35.98	1865	219.4
3	325	19	2.62	40.60	2380	280.0
4	268	21	2.76	36.15	2235	262.9
5	336	21	2.33	38.11	2335	274.7

Table 7 Utilization rate of phosphorus by rape (*Brassica napus* L.)

Treatment	Biomass g/plant	Content of P mg/plant	Utilization of P	
			Fertilizer-P	rate/%
1	27.00	37.1	0	0
2	61.24	123.8	86.7	13.87
3	66.93	103.0	65.9	10.54
4	66.03	154.9	116.9	18.70
5	76.14	152.8	115.7	9.26

The utilization rate of phosphorus from phosphate fertilizer is evaluated by the different method. Table 7 shows that the grain yield of rape (*Brassica napus* L.) is not directly related to the utilization rate of phosphorus from phosphate fertilizer. The grain yield of the rape treated with the GPR from Liuyang, Hunan province is the highest but utilization rate of phosphorus is the lowest. In treatment 5 the amount of GPR applied is as twice as that in treatment 4, but the yield in microplot do not increase so that the utilization rate of phosphorus decreases. This result is the same as that in pot experiment, indicating that the optimum amount of the phosphate fertilizer applied is very important for obtaining the best result.

3 CONCLUSIONS

(1) Applying the GPRs to the acid red soil can provide phosphorus for the growth and development of the rape (*Brassica napus* L.). The pod number of rape increased and plump-eared so that the yield went up by twice compared with that of

control.

(2) The availability of phosphorus (P_2O_5) from the GPRs by the rape (*Brassica napus* L.) is investigated by ^{32}P tracer technique and about 17.1% is from calcium superphosphate. It is calculated that fertilizer efficiency of 8.53 kg GPR from Guizhou province is equal to that of 1 kg calcium superphosphate.

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