PHOSPHATE ROCK APPLICATION ON ALFALFA (*Medicago sativa* L.) PRODUCTION AND MACRONUTRIENTS IN LATOSOL SOIL

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ABSTRAK

Penelitian dilakukan untuk mengetahui pengaruh aplikasi batuan fosfat pada produksi dan kandungan makronutrien alfalfa dibandingkan dengan pupuk fosfat kimia. Penelitian menggunakan rancangan acak lengkap yang berpola faktorial 3x3. Faktor pertama adalah sumber pupuk P yang berbeda: Guizhou Phosphate Rock (GPR), Jingxiang Phosphate Rock (JPR), dan Single Super Phosphate (SSP). Faktor kedua adalah dosis pupuk P: 75, 100, dan 125 mg P_2O_5/kg tanah. Perlakuan kontrol (tanpa penambahan pupuk P, CK) telah ditambahkan sebagai perbandingan dengan perlakuan. Hasil menunjukkan bahwa produksi alfalfa tertinggi dihasilkan dari penambahan JPR, dimana GPR dan SSP menghasilkan kandungan nutrien lebih tinggi pada alfalfa disbanding dengan JPR. Kesimpulan dari penelitian ini adalah aplikasi batuan fosfat memiliki efek yang sama pada pertumbuhan alfalfa dibandingkan dengan SSP pada kondisi perlakuan tersebut.

Kata kunci: alfalfa, batuan fosfat, makronutrien, produksi

ABSTRACT

The objective of this study was to evaluate the effectiveness of phosphate rocks (PRs) fertilizer compared to chemical P fertilizer for the best crop production and macronutrients of alfalfa. A completely randomized design under 3x3 factorial patterns was used in this research. The first factor was different sources of P fertilizer: Guizhou Phosphate Rock (GPR), Jingxiang Phosphate Rock (JPR), and Single Super Phosphate (SSP). The second factor was level of P fertilizer: 75, 100, and 125 mg P_2O_5/kg soil. A control treatment (without addition of P fertilizer, CK) was added as a comparison with the treatments. The results showed that JPR was the best for alfalfa production, whereas GPR and SSP were better for nutrient content in the alfalfa tissue than JPR. On the whole, phosphate rocks had similar effect on alfalfa growth compared to SSP at the experimental conditions.

Keywords: alfalfa, macronutrients, phosphate rock, production

INTRODUCTION

Phosphorus (P) is one of the essential nutrients for plants, but the least available mineral nutrients to the plants in many cropping environments (Shenoy and Kalagudi, 2005). Although P is quite abundant in soil but it reacts readily with iron, aluminum and calcium to form insoluble compounds and only a small proportion is immediately available to plants (Hinsinger, 2001; Lehmann *et al*., 2001; Richardson *et al*., 2009). The PRs are generally less water-soluble and slow release in soil, but it requires minimum processing and lower in cost per unit of P, and effective under specific condition of soil management (Chien and Menon, 1995; Srivastava *et al*., 2007), so direct application of PRs to soil will help to reduce the cost of producing soluble P fertilizer and increase the crop production (Ahiabor and Hirata, 2003). Almost all of crops have a good yield response to chemical P fertilizer application, but the efficiency of phosphate rocks (PR) application varies greatly with plant species and mineralogical properties of PR (Jiang *et al*., 1990).

Alfalfa is one of the best forage among other feed crops (Markovic *et al*., 2009). Alfalfa is a kind of plant rich in protein, fiber, and mineral substances for animal nutrition, especially for ruminants (Katic *et al*., 2009). Forage crops are the sources of livestock nutrition, thus the management of forage crop production such alfalfa is important (Eskandari *et al*., 2009). Legume requires a large amount of P for symbiosis with rhizobia, so it is important to improve P acquisition (Graham and Vance, 2000). Many researches have been conducted to improve the alfalfa P-uptake, production and macronutrients with an adequate amount of chemical P fertilizer, but few data focus on direct application of PR to improve the alfalfa P-uptake, production and macronutrients in latosol soil. The objective of this study was to evaluate the effect of PRs application compared to chemical phosphate fertilizer on the best P-uptake, production and macronutrients of alfalfa in latosol soil.

MATERIALS AND METHODS

The latosol soil was collected from the top layer of 0-20 cm depth from Hainan Province, China for this experiment. The properties of latosol soil are shown at Table 1. Two sources of PRs were collected from Guizhou, China and Jingxiang, Hubei, China compared with chemical P fertilizer as SSP. The properties of PRs are shown at Table 2. Alfalfa (cv. Algonquin) was used as test crop to evaluate the effectiveness of PRs. USDA 1002 strain of *Shinorbium meliloti* was cultured in YMB (Yeast Manitol Brooth) liquid for inoculation.

A randomized factorial design 3x3 was used in this research. The first factor was different sources of P fertilizer: GPR, JPR, and SSP. The second factor was level of P fertilizer: 75, 100, 125 mg P_2O_5/kg soil (Table 3). A control treatment (without addition of P fertilizer, CK) was added as a comparison with the treatments.

Latosol soil was put in plastic pots as 5 kg/pot. P fertilizers were applied to the soil as the treatments, N and K fertilizer were applied in the same amount (0.15 g/kg) as basal fertilizer for all treatments as urea and KCl including CK. Five plants of alfalfa per pot were grown in a green house. Pots were inoculated with 5 mL/plant of YMB liquid medium containing *Shinorbium meliloti* at two weeks after sowing. The plants were grown in summer for 4 months (early May – early September). The plants were watered everyday to keep the moisture at 70% of field water capacity.

The plant samples were separated into leaves and stems. The fresh and dry plant samples were weighed for dry matter yield (DMY). The plant

Table 1. Latosol Soil Properties

Properties	Amount
pH	6.06
Organic Carbon (g/kg)	14.35
Sand (2-0.05 mm) (%)	26.43
Silt (0.05-0.002 mm) (%)	28.77
Clay (<0.002 mm) (%)	44.80
Total N (g/kg)	1.11
Available N (mg/kg)	69.61
Total P (g/kg)	1.23
Available P (mg/kg)	24.56
Total K (g/kg)	0.90
Available K (mg/kg)	209.5
CEC (Cmol/kg)	17.07

Table 2. The Properties of Phosphate Rocks (PR)

Compounds	Guizhou PR (GPR)	Jingxiang PR (JPR)
P_2O_5 (%)	35.6	23.2
CaO (%)	52.0	38.1
Fe_2O_3 (%)	0.20	38.5
Al_2O_3 (%)	0.20	0.109
MgO (%)	0.30	1.46
Pb (mg/kg)	*	18.9
Cu (mg/kg)	*	13.8
Zn (mg/kg)	*	20.1
Cd (mg/kg)	*	*
Available P (%)	7.20	2.6

*: below detection limit

biomass of each part were oven dried at 60-70 °C and ground into fine powder using mechanical grinder then digested with H_2SO_4 and H_2O_2 for N, P, K analysis. P content was analyzed using ultraviolet-visible spectrometer, and N concentration was determined by automatic nitrogen analyzer (Hanon K9840) and K content was estimated by flame photometer. The dry matter yield and the P concentration in plant tissues were used to calculate the P-uptake (Prochnow *et al*., 2006).

Statistical Analysis

The data were analyzed statistically by analysis of variance using SAS software. The

Table 3. The Doses of Phosphate Fertilizers Applied (g/pot)

Sources of Phosphate Fertilizer	P Level (mg P_2O_5/kg soil)		
	75	100	125
Guizhou PR	1.28	3.01	4.73
Jingxiang PR	3.54	8.32	13.11
SSP	0.83	1.96	3.08

Table 4. The Growth of Alfalfa in Latosol Soil Affected by P Applied

Treatment	Height of plant (cm)	Number of Tillers	Number of Leaves
CK	69.30^{g}	27^{ed}	886^{cdef}
GPR- 75	74.46^{f}	26^{ef}	1110^{bc}
100	85.20^{c}	29^{cde}	989^{cd}
125	85.13^{c}	36^{a}	955^{cde}
JPR- 75	95.80^{a}	29^{bcd}	1394^{a}
100	87.86^{b}	32^{b}	839^{defg}
125	82.83^{d}	27^{def}	633^{g}
SSP- 75	88.18^{b}	24^{f}	718^{fg}
100	79.64^{e}	27^{def}	742^{efg}
125	82.82^{d}	31^{bc}	1219^{ab}

Different superscript in the same column shows significant differences ($P \leq 0.05$)
*= significant

differences among treatments were compared by Duncan's Multiple Range Tests (DMRT).

RESULTS AND DISCUSSION

Alfalfa Production Used Different P Fertilizers

The alfalfa production was measured as growth and forage yield. Alfalfa growth was measured as plant height (PH), number of tillers (NT) and number of leaves (NL). The mean data of each parameter are presented in Table 4. The different source of P, level of P fertilizers and interaction between them had significant effect to PH and NT. PH significantly increased with P application as 5.16-26.50 cm more than CK. The highest PH was 95.80 cm resulted by the JPR 75. JPR 125 and SSP 100 resulted the same amount in NT compared to CK. The highest NT was resulted by GPR 125. The average data showed that GPR, JPR, and SSP resulted the same NT, whereas 125 P level was better than 100 and 75 P level. NL was not significantly affected by the different source of P fertilizers, but the level of P fertilizers and the interaction between two factors had significantly effect to NL. There was no significant different between JPR 75 and SSP 125 in NL (1394 and 1219, respectively). JPR was a good P fertilizer source for alfalfa growth in which resulted the highest PH and NL in the level 75. The higher P level of JPR application was not suggested due to it decreased the alfalfa growth. Although JPR is the low availability of P fertilizer source but at the low P fertilizer application it could increase alfalfa growth higher than GPR and SSP. GPR was needed in the highest P level to increase PH and NT, whereas SSP was needed in the highest P level to increase NT and NL of alfalfa.

The fresh and dry yield in each part of the plant as leaf, stem and total are shown in Table 5. There was an interaction between source and level of P fertilizers for all yield parameters. The source and level of P fertilizers had no significant effect to stem and total fresh yield, and stem dry yield. Leaf and total dry yield were not significantly affected with the source of P fertilizers, whereas

Table 5. The Yield of Alfalfa in Latosol Soil Affected by P Applied

Treatment	Yield (g/pot)					
	Leaf		Stem		Total	
	fresh	dry	fresh	dry	fresh	dry
CK	17.06[cd]	2.71[ef]	22.74[f]	4.59[d]	39.80[de]	7.30[d]
GPR- 75	18.98[c]	3.56[cde]	29.41[cd]	6.89[bc]	48.39[bc]	10.45[c]
100	17.58[cd]	3.46[cde]	30.90[c]	7.33[abc]	48.47[bc]	10.79[bc]
125	16.54[cd]	3.05[def]	30.48[cd]	6.80[bc]	47.02[bcd]	9.84[c]
JPR- 75	29.24[a]	5.04[a]	40.04[a]	8.20[a]	69.27[a]	13.24[a]
100	22.68[bc]	4.20[abc]	26.96[de]	6.83[bc]	49.64[b]	11.03[bc]
125	11.98[d]	2.17[f]	23.59[ef]	5.39[d]	35.57[e]	7.56[d]
SSP- 75	17.47[cd]	3.13[de]	23.63[ef]	6.53[c]	41.09[cde]	9.66[c]
100	21.77[bc]	3.97[bcd]	29.65[cd]	7.25[abc]	51.42[b]	11.22[bc]
125	27.24[ab]	4.60[ab]	35.98[b]	7.65[ab]	63.22[a]	12.25[ab]

Different superscript in the same column shows significant differences ($P \leq 0.05$).
*= significant

the level of P fertilizers had no significant effect to leaf fresh yield. All of the treatments resulted the higher total fresh yield as 1.29-29.47 g/pot than CK, except JPR 125 which was lower 4.24 g/pot than CK. The total dry yield was higher than CK in all of treatments in the range 0.26-5.94 g/pot. Fresh and dry yield did not increase significantly with increasing P level of GPR, but decreased with increasing P level of JPR either fresh or dry yield. However, fresh and dry yield were increased with increasing P level of SSP. There was no significant difference between JPR 75 and SSP 125 in increasing leaf and total fresh yield, but JPR 75 was better for increasing stem fresh yield than others. The best forage dry yield was resulted by JPR 75 and SSP 125 applications as 13.24 and 12.25 g/pot, respectively. There was no significantly different among them for increasing forage dry yield (leaf, stem and total).

Based on the result of plant growth and forage yield, its implied that JPR 75 resulted a good alfalfa production comparable with SSP, except for number of tiller. However, the higher level of JPR application decreased the alfalfa production. GPR also could increase the alfalfa production compared to CK, but it was needed in the higher P level. Only a fraction (30-50% of P dissolved from PR) becomes available for plant uptake because most of the P dissolved from PR goes through adsorption immediately and immobilization reactions (Bolan and Hedley, 1990). The interest in the use of phosphate rocks as an alternative source of P fertilizer has increased due to the relatively lower cost than the use of chemical P fertilizer and the potential of their utilization (Akande *et al*., 2010). Many researchers mentioned that PR application as P source with inoculation of *Rhizobium* was able to increase the performance of legume. Somado *et al*. (2003) observed that in both the pot and field experiments, there was a significant response of legume performance to PR application. Alfalfa responsed to P fertilizer application in latosol soil. In this study, plant growth and dry matter yield were markedly increased by phosphorus application with the different source of P. According to research conducted by Barea *et al*. (2002), phosphate rock application improved plant growth and shoot biomass. The increasing P level of GPR resulted the same value on alfalfa production, it was likely caused by low PR solubility (Rick *et al*., 2011).

Alfalfa Macronutrients

The alfalfa leaf nitrogen content (range 20.18-27.49 g/kg) was higher than the stem (range 8.36-11.83 g/kg). The different source and level of P fertilizers and the interaction between them had significant effect to nitrogen content in plant tissues, but there was no significant effect on nitrogen in stem with different source of P fertilizers. The highest leaf N content was 27.49 g/kg obtained by JPR 125 which had no significant difference with JPR 100 as 26.61 g/kg. There was no significant difference between the treatments compared to the control for nitrogen content in stem. The highest stem N content values were in SSP 125, GPR 100 and CK (11.83, 11.31 and 10.94 g/kg, respectively). JPR was better in resulting the high N content in leaf than

Table 6. Alfalfa Nutrients Content

Treatment	Leaf			Stem		
	N	P	K	N	P	K
	-----g/kg-----					
CK	20.49[d]	2.08[e]	32.84[bc]	10.94[abc]	3.78[c]	33.36[abc]
GPR- 75	20.18[d]	2.60[cd]	26.76[f]	10.44[bc]	4.50[b]	32.79[abc]
100	22.99[c]	3.03[c]	31.01[cde]	11.31[ab]	3.93[c]	31.43[de]
125	20.49[d]	3.00[cd]	30.08[de]	10.54[bc]	5.23[a]	32.33[cd]
JPR- 75	26.06[b]	3.52[b]	36.18[a]	10.16[c]	3.87[c]	32.65[bc]
100	26.61[ab]	4.48[a]	32.15[bcd]	10.80[abc]	4.45[b]	33.49[ab]
125	27.49[a]	4.18[a]	32.35[bcd]	10.69[bc]	4.52[b]	33.52[ab]
SSP- 75	21.44[d]	3.63[b]	28.95[ef]	8.36[d]	4.42[b]	30.58[e]
100	23.22[c]	4.22[a]	33.96[ab]	10.53[bc]	5.13[a]	32.91[abc]
125	23.74[c]	2.54[d]	31.54[bcd]	11.83[a]	4.55[b]	33.85[a]
	*	*	*	*	*	*

Different superscript in the same column shows significant differences ($p \leq 0.05$).
*= significant

GPR and SSP, whereas GPR and SSP were better in resulting the high N content in stem than JPR.

The range values of phosphorus concentration in leaves were similar to the stems. The different source and level of P fertilizers and the interaction among them significantly affected the phosphorus concentration in both of alfalfa leaf and stem. There was a significant difference for P concentration between the treatments compared to control in both of leaf and stem. All of the P treatments could increase the P concentration in leaf compared to the CK. P concentration in leaf was 0.46-2.40 g/kg higher with the P treatments than the CK. The highest P concentration values in leaf were resulted by JPR 100, SSP 100, JPR 125 (4.48, 4.22, 4.18 g/kg, respectively). JPR and SSP were better than GPR in the level 75 and 100 of P fertilizer applied for resulting P concentration in the leaf tissue, but JPR was superior to GPR and SSP in the level 125 of P fertilizer applied for resulting P concentration in the leaf tissue. However SSP was better than GPR in the level 125 of P fertilizer applied for resulting P concentration increasing in the leaf tissue.

Table 6 showed that the range values of potassium concentration in leaves and stems were similar. The P treatments and the interaction between them have a significant effect to potassium in leaf and stem, but the level of P application had no significant effect to potassium content in leaf. The highest potassium contents in leaf were obtained by addition of JPR 75 and SSP 100 (36.18 and 33.96 g/kg, respectively). There was no significant difference between the treatment compare to the control for potassium content in stem where the highest values were obtained by SSP 125, JPR 125, JPR 100 and control.

Crop species influenced the effect of P fixation on plant-available P from PR. The utilization of PR is more effective in legume than nonlegume crops (Rao *et al*., 1998). The higher plant has the ability to acquire the soluble nutrients from soil sparingly. When there is a demand of P by the shoot, the plants are able to compensate for inadequate P supply by expanding the root surface sorption area (Narang *et al*., 2000). Latosol soil tested contains 24.56 mg/kg of available P before P fertilizer application, this amount might be enough as a P starter for legume priming action in acidification process. Mallarino and Rueber (1997) suggested that PR could be valuable source of P to maintain desirable soil-test values for cropping systems that include forage legumes, it means that PR is suitable as P source for alfalfa

CONCLUSION

PR application in latosol soil was suitable for alfalfa P-uptake, production and macronutrients content. P level 75 mg P_2O_5/kg soil was quite for alfalfa production in this soil. SSP was a good P source for alfalfa in latosol soil, although Guizhou and Jingxiang PR constitute P fertilizer sources comparable to SSP and therefore of great agronomic potentials. It should be pointed out that the present results were obtained in greenhouse pots that may differ from the actual field trials in different soil and plant species. The effect of PR application may have different responses in different soil type and crop species compare to chemical fertilizer.

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