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The potential use of bio-activated potassium-bearing mineral from East Java for K fertilizer

Potensi mineral pembawa kalium asal Jawa Timur yang dibio-aktivasi sebagai pupuk K

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Abstract

Potassium (K) is an essential macro-nutrient for crops to support their development, especially in the early stage of growth. Potassium is found in soils and K-bearing minerals but mainly in an unavailable form. The development of an efficient technique in improvement of K solubilization of K-bearing minerals was very strategic to reduce imported conventional K fertilizers, mainly muriate of potash (MOP). The so-called Bio-Kalium (Bio-K) product was constructed by using locally available K-bearing mineral from East Java. The objective of this research was to determine the efficiency and rational dosage of bio-activation K-bearing mineral in comparison with K conventional fertilizer on the growth of cocoa and oil palm seedlings in greenhouse experiment. The strong technical alkaline solution was used to activate K-bearing mineral. The results showed that the application of 4.2 g/cocoa seedling or 6.4 g/oil palm seedling of bio-activated K bearing mineral containing 10^8 cfu/gram of Burkholderia vietnamiensis *Zeo3 strain (Bio-K) significantly increased of height, leaf number, and stem diameter of the four and six-month-old cocoa and oil palm seedlings respectively.*

[*Keywords: Alkaline, potassium, essential macro-nutrient, cocoa seedling, oil palm seedling, Bio-K*].

Abstrak

Kalium (K) merupakan unsur hara makro esensial yang diperlukan untuk mendukung pertumbuhan tanaman khususnya pada tahap awal perkembangannya. Kalium terdapat di dalam tanah dan mineral pembawa K, tetapi pada umumnya dalam bentuk yang tidak tersedia. Teknik pengembangan untuk meningkatkan kelarutan K dari mineral pembawa K yang efisien sangat strategis untuk mengurangi ketergantungan terhadap pupuk K import, khususnya *muriate of potash* (MOP). Pupuk Bio-Kalium (Bio-K) dikembangkan dengan menggunakan mineral pembawa K lokal yang terdapat di Jawa Timur. Tujuan penelitian ini untuk menetapkan efisiensi dan dosis rasional dari mineral pembawa K yang di aktivasi dan diperkaya dengan bakteri (bio-aktivasi) dibandingkan dengan pupuk K konvensional terhadap pertumbuhan bibit kakao dan kelapa sawit di rumah kaca. Larutan basa kuat teknis digunakan untuk meng-aktivasi mineral pembawa K. Hasil yang diperoleh menunjukkan bahwa aplikasi mineral pembawa K yang diaktivasi dan mengandung 10^8 cfu/g *Burkholderia vietnamiensis* strain Zeo3 (Bio-K) sebanyak 4,2 g/bibit kakao atau 6,4 g/bibit kelapa sawit dapat meningkatkan masing-masing tinggi, jumlah daun, dan diameter batang bibit kakao umur empat bulan dan kelapa sawit umur enam bulan secara signifikan.

[Kata kunci: Basa, kalium, hara-makro esensial, bibit kakao, bibit kelapa sawit, Bio-K]

Introduction

Indonesia is an agricultural country and the development of agriculture depends on its soil productivity. Unfortunately, many soils in Indonesia are considered lack of available potassium to meet optimal crop yield and quality (IIED, 2002). Approximately 90-98% of total K is found in soils and K-bearing minerals but mainly in an unavailable form. In tropical soils, most soil K contents are very low due to low-K soil parent materials and intensive annual rainfall and high temperature (Raheb & Heidari, 2011) as well as fixation by clay minerals. Fixation of K^+ occurs extensively on soils dominated by 2:1 type clay minerals. Under natural soil condition the main source of K for plants growth derives from the weathering of K-bearing minerals (K feldspar, leucite, K mica such as biotite, phlogopite, and glauconite and clay such as illite) and organic K (compost and plant residues). Therefore the use of an alternative activation technology of indigenous resources of soil K minerals such as feldspar and illite are gaining importance to reduce the dependence of imported or costly commercial fertilizers (Hellal *et al*., 2009). van Straaten (2007) reported that the presently use of K-fertilizers is not only soluble and easily available, it is also easily leachable, especially in sandy soils with low organic matter contents. Some potassium-demanding crops like rubber, cocoa, and oil palm may get benefits from the slow release of K from K-bearing minerals. In order to reduce the dependence on imported potash, a local potassium-bearing mineral containing 2.0-2.5% (w/w) of available K_2O was used in this research as it could be a potential K-source for crop production when its solubility could be improved.

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Potassium occurs in feldspar in highly weathered-resistant framework lattice positions. The potassium ion is not easily released and is therefore not suitable for direct application to the plants. Further, Badr (2006) reported that potassium from feldspar mineral was solubilized and transformed into available form as evident from its higher available K when incorporated with organic materials along with inoculation of silicate dissolving bacteria. Furthermore, Sugumaran & Janarthanam (2007) reported that feldspar are readily weathered through the protonation although complexation by some of organic acids and acidic polysaccharides of microbial origin can also play a role. The use of plant growth promoting rhizobacteria (PGPR), including potassium mobilizing bacteria as bio-fertilizers or bio-control agents for agriculture improvement and environmental protection has been a focus of recent researches (Goenadi & Santi, 2009; Girgis *et al*., 2008; Han & Lee, 2006; Hu *et al*., 2006). Some microorganisms in the soil are able to solubilize unavailable forms of K-bearing minerals, such as micas, illite, and orthoclases, by excreting organic acids which either directly dissolves rock K or chelate silicon ions to bring the K into solution. Basak & Biswas (2010) reported that application of potassium solubilizing microorganism is a promising approach to increase K availability in soils. This research was conducted to evaluate the efficiency and rational dosage of bio-activation K-bearing mineral (Bio-K) in comparison with K conventional (MOP) fertilizer on the growth of cocoa and oil palm seedlings.

Materials and Methods

Sources of microorganism

Burkholderia vietnamiensis Zeo3 strain was isolated from zeolite mineral originating from Bayah, West Java. This bacterium was identified by using 16S rRNA gene sequence analysis and was lodged in Microbiology and Environmental Laboratory of Indonesian Biotechnology Research Institute for Estate Crops, Bogor. As a source of inoculum, *B. vietnamiensis* Zeo3 was grown on medium described by Lin Qi-mei *et al*., (2002) consisting of (g/L): 5 g sucrose; 0.005 g $FeCl_3$; 0.5 g $MgSO_4.7H_2O$; 0.1 g $CaCO_3$; 2 g mineral ores (feldspar); pH 7.0-7.4. Previous result indicated that this bacterium is capable of producing citric acid, phosphatase enzyme, and indole acetic acid (IAA).

Formulation of bio-K fertilizer

Potassium bearing minerals i.e. feldspar and illite were obtained from East Java. These minerals contained 2.0-2.5% of available K_2O. The first step of activation was preparing a dilution of 150 g technical KOH in 1L H_2O. Approximately 35% (v/w) of this dilution was used for activate 80-100 mesh of K-bearing mineral and incubate at room temperature by mixing and agitating continuously for two hours. Homogeneous activated K-bearing mineral was then dried and granulated using a pan granulator. A three-day-old culture of potassium-solubilizing bacteria suspension, i.e. *B. vietnamiensis* Zeo3 strain (10^{10}cfu/mL suspension), was added to air dried activated K-bearing mineral using hand sprayer at about 5% (v/w).

Effectiveness of bio-K fertilizer on cocoa and oil palm seedlings

A greenhouse experiment was performed in a factorial arrangement of a Completely Randomized Design, with six levels of Bio-K dosages, and three replications. Bio-K fertilizer were compared with conventional MOP (60% total K_2O) and the dosage applied were: 0.7; 1.4; 2.1; 2.8; 3.5; 4.2 g/cocoa seedling and 1.1; 2.1; 3.2; 4.2; 5.3; and 6.4 g/oil palm seedling. Basic dosages applied for these treatments were equal to 25; 50; 75; 100; 125; and 150% of that recommended dosage for MOP. All treated plots received standard N, P, and Mg fertilizers. The soil used was Ultisol collected from Cikopomayak area, West Java. Soil samples were air dried and passed through 2 mm sieve and analyzed for the following: pH, total carbon, nitrogen, phosphorus, potassium, calcium carbonate content, and soluble cations (Table 1). Upper Amazone Hybrid (UAH) cocoa seedlings and Dura x Pisifera oil palm seedlings obtained from ICCRI (Indonesian Coffee and Cocoa Research Institute) and IOPRI (Indonesian Oil Palm Research Institute) were planted for four and six months respectively. Parameters observed were height, number of leaf, and diameter of stem.

Results and Discussion

Characteristics of activated bio-K fertilizer

The alternative to be dependent on expensive imported K-fertilizer is to exploit local sources of K-bearing minerals in Indonesia potential deposits such as East and West Java, North Sumatera, and Lampung. In our research, we focused on the most important K- bearing mineral from East Java (Figure 1). Table 2 shows the effects of technical alkaline solution treatments on the quality of Bio-K formulation, and evaluated on the basis of total K_2O contents. The activation of K-bearing mineral by using technical alkaline (KOH) increasing of 66.1 up to 79.4% K_2O contents in comparison with initial material with low content of K_2O (2.0-2.5%).

Table 1. Characteristics of Ultisol soil used for cocoa (UAH) and oil palm (DxP) seedlings growth media.
Tabel 1. Karakteristik tanah Ultisol yang digunakan sebagai media tumbuh bibit kakao (UAH) dan kelapa sawit (DxP).

Types of analysis (*Jenis analisa*)	Results (*Hasil*)	Types of analysis (*Jenis analisa*)	Results (*Hasil*)
pH in H_2O	3.5	Cation exchange values:	
pH in KCl 1N	3.0	Na^+ (cmol/kg)	0.3
Carbon (%)	2.1	K^+ (cmol/kg)	0.9
Nitrogen (%)	0.3	Ca^{2+} (cmol/kg)	2.6
P_2O_5 HCl 25% (ppm)	10.6	Mg^{2+} (cmol/kg)	1.1
P Bray (ppm)	3.7	Texture :	
K_2O HCl 25% (ppm)	470.7	sand (%)	10.7
MgO HCl 25% ppm)	351.8	silt (%)	14.7
CaO HCl 25% (ppm)	396.4	clay (%)	74.6
CEC (cmol/kg)	32.5	Al exc. (cmol/kg)	0.2

Figure 1. Some of potassium bearing mineral samples from East Java.
Gambar 1. Beberapa contoh mineral pembawa kalium asal Jawa Timur.

Table 2. The activated of potassium-bearing minerals with technical alkaline solution.
Tabel 2. Aktivasi mineral pembawa kalium dengan larutan basa teknis.

Mineral's Code	Initial K-bearing mineral [total of K_2O (%)]	Activated of K-bearing mineral [total of K_2O (%)]
A	2.1	9.3
B	2.1	10.2
C	2.5	11.6
D	2.3	10.7
E	2.0	7.7
F	2.0	8.1
G	2.5	11.4
H	2.0	7.5
I	2.0	5.9

Bio-K fertilizer has a granular type with 3-5 mm in diameter, with color white or light green, depending on the color of initial material of potassium-bearing mineral. Specification of Bio-K is containing 5-10% K_2O and 10^8 cfu *Burkholderia vietnamiensis* ZEO-3 strain bacteria per gram products, strong hardness, and moderate on dissolve in water (Figure 2).

Figure 2. Bio-K granular fertilizer, 3-5 mm in diameter.
Gambar 2. Pupuk Bio-K granul dengan diameter 3-5 mm

Effectiveness of Bio-K fertilizer on cocoa and oil palm seedlings

Application dosages 2.8 g/cocoa seedling and 6.4 g/oil palm seedling of bio-activated potassium bearing mineral containing 10^8 cfu of *B. vietnamiensis* Zeo3 strain (Bio-K) resulted in significant increase of height and leaf number of the four and six-months old cocoa and oil palm seedlings, respectively (Table 3 & 4), compared to those of the MOP treatment. Dosages application of Bio-K at 1.4-4.2 g/cocoa seedling and 2.1-6.4 g/oil palm seedling, increased total dry weight seedlings by 6 – 52% and 20 – 45% over the MOP treatment after four and six months planting, respectively. Our treatment recorded that inoculating activated K-bearing minerals with K- solubilizing bacteria may exert beneficial effects to plant growth. Growth enhancement by *B. vietnamiensis* Zeo3 strain may also relate to its ability to produce hormones, especially IAA. In our research, *B. vietnamiensis* Zeo3 strain was applied as K solubilizing bacteria with high potential in production of citric acid, phosphatase enzyme,and plant growth promoting hormone i.e. 9.3 ppm; 94.9 µm; and 57.9 ppm, respectively.

The genus *Burkholderia* comprises more than 40 different species which occupy a wide array of ecological niches (Villarreal & Mellado, 2010). Particularly in recent years, a growing number of *Burkholderia* strains and species with beneficial interactions with their host plants have been reported, e.g. N_2-fixing *Burkholderia* species like *B. vietnamiensis* or other genus *Burkholderia* for nodulating and endophytes with high activities of the enzyme 1-aminocyclopropane-1-carboxylate (ACC) deaminase (Vandamme *et al*., 2007) and plant growth promoting hormone (PGPR). Sheng, (2005) and Girgis *et al*., (2008) proved that the bioavailability of K in soils increase with inoculation of PGPR bacteria or with combined inoculation and potassium-bearing mineral. It is may lead to increasing K uptake and plant growth. Furthermore, Lucas Garcia *et al*., (2004) found that inoculation with bacteria, which can improve K availability in soils by producing organic acid, stimulated growth and mineral uptake of plant. Table 7 showed that after four months application of Bio-K, significantly increased N uptake by cocoa leaf seedlings. On the other hand, no significant differences in leaf uptake of N, P, Mg in oil palm seedlings. Furthermore, there were significant different between MOP and Bio-K applied on leaf uptake of K. This might be due to granular form of Bio-K, which solubilized so slowly in Ultisol soil with lower content K than MOP which results in K becoming generally not available to seedlings during the growing periods. However, there was no nutrient deficient zone in close to seedlings. The differences in leaf K uptake type between cocoa and oil palm seedlings (Table 7 & 8) are not well understood. Baligar (1985) reported that the mechanism of K supply to different crop species is attributable to differences in the K requirements, water flux rates and to the differences in root parameters.

Table 3. Seedlings growth of cocoa UAH clone with NPMg fertilizer and Bio-K treatments, four months after planting.
Tabel 3. Pertumbuhan bibit kakao klon UAH dengan perlakuan pupuk NPMg dan Bio-K, empat bulan setelah tanam.

Treatments (*Perlakuan*)	Height (*Tinggi*) (cm)	Leaf Number *Jumlah daun*	Stem diameter *Diameter batang* (cm)
Full rate NPMg MOP dosages	51.1 bc*)	24.8 bc	1.0 ab
Full rate NPMg dosages + 0.7 g/seedling of Bio-K	40.3 d	22.0 c	0.9 bc
Full rate NPMg dosages + 1.4 g/seedling of Bio-K	56.1 ab	27.8 ab	1.1 a
Full rate NPMg dosages + 2.1 g/seedling of Bio-K	47.5 c	29.0 ab	0.9 bc
Full rate NPMg dosages + 2.8 g/seedling of Bio-K	63.0 a	30.3 a	1.0 ab
Full rate NPMg dosages + 3.5 g/seedling of Bio-K	44.3 cd	27.0 ab	1.0 ab
Full rate NPMg dosages + 4.2 g/seedling of Bio-K	56.8 ab	30.0 a	1.0 ab
Blank	44.5 cd	25.0 bc	0.8 c
Coefficient variable (%)	9.12	11.0	8.9

*) Number in the same column followed by similar letter(s) are not significantly different according to Duncan Multiple Range Test (P<0.05).

*) *Angka dalam kolom yang sama diikuti oleh huruf yang sama berarti tidak berbeda nyata menurut uji jarak berganda Duncan pada (P< 0,05).*

Table 4. Seedlings growth of oil palm DxP clone with NPMg fertilizer and Bio-K treatments, six months after planting.
Tabel 4. Pertumbuhan bibit kelapa sawit klon DxP dengan pupuk NPMg dan Bio-K, enam bulan setelah tanam.

Treatments (*Perlakuan*)	Height (*Tinggi)* (cm)	Leaf Number *Jumlah daun*	Stem diameter *Diameter batang* (cm)
Full rate NPMg MOP dosages	68.4 abc*)	11.8 b	2.4 bc
Full rate NPMg dosages + 1.1 g/seedling of Bio-K	67.6 bc	11.8 b	2.4 bc
Full rate NPMg dosages + 2.1 g/seedling of Bio-K	68.4 abc	13.0 a	2.5 abc
Full rate NPMg dosages + 3.2 g/seedling of Bio-K	66.9 c	13.0 a	2.5 abc
Full rate NPMg dosages + 4.2 g/seedling of Bio-K	68.8 ab	13.2 a	2.6 ab
Full rate NPMg dosages + 5.3 g/seedling of Bio-K	68.6 ab	13.0 a	2.5 abc
Full rate NPMg dosages + 6.4 g/seedling of Bio-K	69.8 a	13.4 a	2.8 a
Blank	54.0 d	11.8 b	2.3 c
Coefficient variable (%)	1.7	4.9	8.9

*) Number in the same column followed by similar letter(s) are not significantly different according to Duncan Multiple Range Test (P<0,05).

*) *Angka dalam kolom yang sama diikuti oleh huruf yang sama berarti tidak berbeda nyata menurut uji jarak berganda Duncan pada (P< 0,05).*

Table 5. Effects of Bio-K application on four-month-old cocoa seedlings dry weight.
Tabel 5. Pengaruh aplikasi Bio-K terhadap berat kering bibit kakao umur empat bulan.

Treatments (*Perlakuan*)	Leaf (*Daun*) (g)	Stem (*Batang*) (g)	Root (*Akar*) (g)	Total d.w	% to MOP
Full rate NPMg MOP dosages	10.1 bc	6.1 c	7.2 c	23.4 cd	100
Full rate NPMg dosages + 0.7 g/seedling of Bio-K	9.7 bc	5.2 c	6.6 c	21.5 d	91.9
Full rate NPMg dosages + 1.4 g/seedling of Bio-K	10.3 b	7.9 b	6.7 c	24.9 c	106.4
Full rate NPMg dosages + 2.1 g/seedling of Bio-K	12.2 a	9.4 ab	7.5 bc	29.1 b	124.4
Full rate NPMg dosages + 2.8 g/seedling of Bio-K	13.2 a	10.2 a	8.0 bc	31.4 b	134.2
Full rate NPMg dosages + 3.5 g/seedling of Bio-K	12.3 a	10.6 a	8.7 b	31.6 b	135.0
Full rate NPMg dosages + 4.2 g/seedling of Bio-K	13.9 a	10.8 a	10.9 a	35.6 a	152.1
Blank	8.3 c	4.7 c	5.0 d	18.0 e	76.9
Coefficient variable (%)	9.3	13.5	10.3	5.1	

*) Number in the same column followed by similar letter(s) are not significantly different according to Duncan Multiple Range Test (P<0,05).

*) *Angka dalam kolom yang sama diikuti oleh huruf yang sama berarti tidak berbeda nyata menurut uji jarak berganda Duncan pada (P< 0,05).*

Table 6. Effects of Bio-K application on six-month-old oil palm seedlings dry weight.

Tabel 6. Pengaruh aplikasi Bio-K terhadap berat kering bibit kelapa sawit umur enam bulan.

Treatments/*Perlakuan*	Leaf /*Daun* (g)	Stem/*Batang* (g)	Root/*Akar* (g)	Total d.w	% to MOP
Full rate NPMg MOP dosages	14.4 c	15.8 b	12.3 a	42.5 d	100
Full rate NPMg dosages + 1.1 g/seedling of Bio-K	15.9 c	16.1 b	9.0 cd	41.0 d	96.5
Full rate NPMg dosages + 2.1 g/seedling of Bio-K	19.8 b	22.6 a	9.9 cd	52.3 c	123.1
Full rate NPMg dosages + 3.2 g/seedling of Bio-K	18.8 b	22.9 a	9.3 cd	51.0 c	120.0
Full rate NPMg dosages + 4.2 g/seedling of Bio-K	21.3 b	24.2 a	13.0 a	58.5 ab	137.6
Full rate NPMg dosages + 5.3 g/seedling of Bio-K	20.4 b	23.5 a	10.4 bc	54.3 bc	127.8
Full rate NPMg dosages + 6.4 g/seedling of Bio-K	24.3 a	25.6 a	11.7 ab	61.6 a	144.9
Blank	13.8 c	16.4 b	8.7 d	38.9 d	91.5
Coefficient variable (%)	8.3	8.4	8.7	5.1	

*) Number in the same column followed by similar letter(s) are not significantly different according to Duncan Multiple Range Test (P<0,05).

*) *Angka dalam kolom yang sama diikuti oleh huruf yang sama berarti tidak berbeda nyata menurut uji jarak berganda Duncan pada (P< 0,05).*

Table 7. Nutrient uptake of N, P, K, Mg by cocoa seedlings leaf four months after Bio-K application.

Tabel 7. Serapan nutrisi N, P, K, Mg daun bibit kakao empat bulan setelah aplikasi Bio-K.

Treatments/*Perlakuan*	N (%)	P (%)	K (%)	Mg (%)
Full rate NPMg MOP dosages	2.31 b	0.29 a	1.75 a	0.41 a
Full rate NPMg dosages + 0.7 g/seedling of Bio-K	2.07 c	0.26 a	0.83 cd	0.42 a
Full rate NPMg dosages + 1.4 g/seedling of Bio-K	2.26 bc	0.24 a	0.98 bc	0.40 a
Full rate NPMg dosages + 2.1 g/seedling of Bio-K	2.26 bc	0.21 a	1.05 b	0.41 a
Full rate NPMg dosages + 2.8 g/seedling of Bio-K	2.56 a	0.23 a	0.85 bcd	0.41 a
Full rate NPMg dosages + 3.5 g/seedling of Bio-K	2.21 bc	0.27 a	0.74 d	0.41 a
Full rate NPMg dosages + 4.2 g/seedling of Bio-K	2.36 b	0.29 a	0.98 bc	0.41 a
Blank	1.35 d	0.21 a	0.42 e	0.37 b
Coefficient variable (%)	5.9	10.8	12.0	4.17

*) Number in the same column followed by similar letter(s) are not significantly different according to Duncan Multiple Range Test (P<0,05).

*) *Angka dalam kolom yang sama diikuti oleh huruf yang sama berarti tidak berbeda nyata menurut uji jarak berganda Duncan pada (P< 0,05).*

Table 8. Nutrient uptake of N, P, K, Mg by oil palm seedlings leaf, six months after Bio-K application.

Tabel 8. Serapan nutrisi N, P, K, Mg daun bibit kelapa sawit enam bulan setelah aplikasi Bio-K.

Treatments/*Perlakuan*	N (%)	P (%)	K (%)	Mg (%)
Full rate NPMg MOP dosages	2.99 a	0.25 a	1.61 a	0.36 a
Full rate NPMg dosages + 1.1 g/seedling of Bio-K	3.26 a	0.25 a	0.78 b	0.37 a
Full rate NPMg dosages + 2.1 g/seedling of Bio-K	3.42 a	0.27 a	0.78 b	0.38 a
Full rate NPMg dosages + 3.2 g/seedling of Bio-K	3.33 a	0.25 a	0.78 b	0.44 a
Full rate NPMg dosages + 4.2 g/seedling of Bio-K	3.25 a	0.22 a	0.73 b	0.41 a
Full rate NPMg dosages + 5.3 g/seedling of Bio-K	3.17 a	0.24 a	0.72 b	0.39 a
Full rate NPMg dosages + 6.4 g/seedling of Bio-K	3.23 a	0.23 a	0.95 b	0.37 a
Blank	2.11 b	0.23 a	0.45 c	0.35 a
Coefficient variable (%)	6.9	6.7	10.5	7.3

*) Number in the same column followed by similar letter(s) are not significantly different according to Duncan Multiple Range Test (P<0,05).

*) *Angka dalam kolom yang sama diikuti oleh huruf yang sama berarti tidak berbeda nyata menurut uji jarak berganda Duncan pada (P< 0,05).*

Conclusions

This study indicates that the activation of K-bearing mineral from East Java by using technical alkaline (KOH) increased K_2O contents in comparison with its origin material with low content of K_2O. Dosages application of Bio-K containing 10^8 cfu *B. vietnamiensis* Zeo3 strain at 4.2 g/cocoa and 6.4 g/oil palm seedlings were recommended to achieve the best vegetative growth of the seedlings.

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References

Badr (2006). Efficiency of K-feldspar combined with organic materials and silicate dissolving bacteria on tomato yield. *J Appl Sci Res* 2(12), 1191-1198.

Baligar VC (1985). Potassium uptake by plants as characterized by root density, species and K/Rb ratio. *Plant & Soil* 85(1), 43-53.

Basak BB & DR Biswas (2010). Co-inoculation of potassium solubilizing and nitrogen fixing bacteria on solubilization of waste mica and their effect on growth promotion and nutrient acquisition by a forage crop. *Biol Fertil Soils* 46, 641–648.

Goenadi DH & LP Santi (2009). Introduction of microbial inoculants to improve fungsional relationship between above- and below-ground bio-diversity. *Menara Perkebunan.* 77(1), 58-67.

Girgis MGZ, MA Heba, Khalil & MS Sharaf (2008). In vitro evaluation of rock phosphate and potassium solubilizing potential of some *Bacillus* strains. *Australian J Basic Appl Sci* 2(1), 68-81.

Han HS, Supanjani & KD Lee (2006). Effect of co-inoculation with phosphate and potassium solubilizing bacteria on mineral uptake and growth of pepper and cucumber. *Plant Soil Env* 52(3), 130-136.

Hellal FA, MA El-hady & AAM Ragab (2009). Influents of organic amendments on nutrient availability and uptake by faba bean plants fertilized by rock phosphate and feldspar. *American-Eurasian J Agric Env Sci* 6(3), 271-279.

Hu X, J Chen& J Guo (2006). Two phosphate-and potassium-solubilizing bacteria isolated from Tianmu Mountain. *World J Microbiol Biotechnol* 22, 983–990.

International Institute for Environment Development (IIED). (2002). *Potash Case Study: Information Supplied By The International Fertilizer Industry Association*. England, Mining Mineral and Sustainable Development. Februari 2002 No. 65 p. 1-9.

Lucas Garcia, JA, A Probanza, B Ramos, J Barriuso & FJ Gutierrez Manero (2004). Effects of inoculation with plant growth promoting rhizobacteria (PGPRs) and *Sinorhizobium fredii* on biological nitrogen fixation, nodulation and growth of *Glycine max* cv. Osumi. *Plant & Soil* 267, 143-153.

Qi-mei L, R Zheng-Hug, S Yan-Xing, Y Jun, & X Li-Jun (2002). Identification and practical application of silicate-dissolving bacteria. *Agric Sci China* 1,81-85.

Raheb A & A Heidari (2011). Clay mineralogy and its relationship with potassium forms in some paddy and non-paddy soils of northern Iran. *Aust J Agric Eng* 2(6), 169-175.

Sheng XF (2005). Growth promotion and increased potassium uptake of cotton and rape by a potassium releasing strain of *Bacillus edaphicus*. *Soil Biol Biochem* 37, 1918–1922.

Sugumaran P & B Janarthanam (2007). Solubilization of potassium containing minerals by bacteria and their effect on plant growth. *World. J Agric Sci* 3(3), 350-355.

Vandamme P, K Opelt, N Knochel, C Berg, S Schonmann, E De Brandt, L Eberl, E Falsen & G Berg (2007). *Burkholderia bryophila* sp. nov. and *Burkholderia megapolitana* sp. nov., moss-associated species with antifungal and plant-growth-promoting properties. *Int. J Sys Evol Microbiol* 57, 2228–2235.

van-Straaten P (2007). *Agrogeology: The Use of Rocks for Crops.* Department of Land Resource Science University of Guelph, Guelph, Ontorio Canada. Enviroquest Ltd., 352 River Road, Cambridge, Ontario N3C 2B7. Canada. 440 p.

Villarreal AW & JC Mellado (2010). Rapid identification of nitrogen-fixing and legume- nodulating Burkholderia species based on PCR 16S rRNA species-specific oligonucleotides. *Syst Appl Microbiol* 2010 31(1), 35-43.