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POTASSIUM DYNAMIC AND AVAILABILITY FROM COMPOSTED AND UNCOMPOSTED RICE STRAW

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By

MULYADI

Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of Agricultural Science in the Faculty of Agriculture
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Dedicated to

Allah S. W. T.,

my Parents,

my wife Dyah Tri M. H.,

my children Alfistia Md.

and Yogi C. A.

Abstract of the thesis submitted to the Senate of Universiti Putra Malaysia in fulfilment of the requirement of the degree of Master of Agricultural Science.

POTASSIUM DYNAMIC AND AVAILABILITY FROM COMPOSTED AND UNCOMPOSTED RICE STRAW

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Chairmain: Ahmad Husni Mohd. Hanif, Ph.D.

Faculty: Agriculture

Managing rice straw (in term of K source) is essential if sustainability is to be achieved with a small amount of inorganic K fertilizer. About 80 % K taken up by rice crop (*Oryza sativa* L.) is in the straw. To increase efficiency of K utilization from the rice straw, it is essential to know the K supplying characteristic and crop available K from the straw. Information of this kind may also help in a better understanding of K cycling in soil--crop system.

Two experiments were conducted in a glasshouse. The first experiment, composting of rice straw, was to study the changes in tensile load of rice straw during rice straw composting, its possibility as an indicator for the state of decomposition and K released. The second experiment, a pot experiment using corn (*Zea mays* L.) variety of PJ-58 as test crop for K uptake planted on Bungor series soil (Typic Paleudult), was firstly to evaluate the crop available K from composted (CRS) and uncomposted (UCRS) rice straw compared to that from Muriate of Potash (MOP) as standard K

fertilizer and secondly to evaluate the use of tensile load of rice straw as an indicator to predict K released from UCRS incorporated in the soil, the crop K uptake and leaf K concentration.

The results indicated that during composting of rice straw, the individual relationships between the percentage of organic matter remaining, the contents of total and water soluble K of decomposing rice straw with the tensile load of indicator rice straw are highly significant ($P \leq 0.01$) with linear correlation coefficients of 0.97, - 0.96 and - 0.94, respectively. Therefore, tensile load of indicator rice straw can possibly be used as an alternative indicator for the state of decomposition of rice straw and to predict K released. Applications of MOP, CRS and UCRS to the soil increased K accumulated in corn crop, total and exchangeable K contents of the soil, but their increase depends on the crop growth period, the K rate and availability of fertilizer applied. Compared to MOP and UCRS, the use of CRS is more beneficial in increasing the crop K, P and Ca uptake and results in better crop growth. As a source of K, the K availability from CRS was more readily available than that from UCRS and MOP; however at 56 days after planting (tasseling stage) and a rate of 360 mg K pot^{-1} (90 kg K ha^{-1}), the crop available (uptake) K from the three K fertilizer sources were similar, ranging from 90.48 to 109.25 %. Tensile load of indicator rice straw can also possibly be used as indicator to predict K released from UCRS incorporated into the soil based on the correlation of tensile load and K content in the decomposing rice straw during composting. The trends are less applicable as indicator to predict the crop K uptake and leaf K concentration of corn.

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KEDINAMIKAN DAN KEDAPATAN KALIUM DARIPADA JERAMI PADI YANG DIKOMPOS DAN TIDAK DIKOMPOS

Oleh

MULYADI

Disember 2000

Pengerusi: Ahmad Husni Mohd. Hanif, Ph.D.

Fakulti: Pertanian

Pengurusan jerami padi (dalam konteks sumber K) adalah penting untuk mencapai kelestarian dengan pertambahan baja K tak organik yang sedikit. Lebih kurang 80 % K yang diserap oleh padi (*Oryza sativa* L.) adalah di dalam jeraminya. Untuk meningkatkan kecekapan penggunaan K daripada jerami padi, adalah penting untuk mengetahui sifat pembekalan K serta K tersedia untuk tanaman daripada jerami padi. Maklumat sebegini membantu pemahaman yang lebih mendalam mengenai kitaran K di dalam sistem tanah-tanaman.

Dua percubaan telah dijalankan di rumah kaca. Percubaan pertama, pengkomposan jerami padi, adalah untuk melihat perubahan galasan tensil jerami padi semasa proses pengkomposan jerami padi, dan kemungkinan ia sebagai penunjuk untuk menyatakan pereputan dan K yang dibebaskan. Percubaan kedua, menggunakan tanaman jagung (*Zea mays* L.) varieti PJ-58 sebagai tanaman ujian untuk

pengambilan K yang ditanam pada tanah siri Bungor (Tipik Paleudult), adalah pertamanya untuk menilai K tersedia untuk tanaman daripada jerami padi dikompos (CRS) dan jerami padi tidak dikompos (UCRS) berbanding dengan "Muriate of Potash" (MOP) sebagai baja K yang piawai dan keduanya untuk menilai kegunaan galasan tensil jerami padi sebagai penunjuk untuk meramal K yang dibebaskan daripada jerami padi yang dimasukkan ke dalam tanah, pengambilan K oleh tanaman dan kandungan K daun.

Keputusan-keputusan menunjukkan bahawa semasa pengkomposan jerami padi, hubungan antara peratus sisa bahan organik, kandungan jumlah K dan kandungan K larut air daripada jerami padi yang sedang mereput dengan galasan tensil daripada jerami penanda adalah sangat nyata ($P \leq 0.01$) dengan koeffisien korelasi linear masing-masing 0.97, - 0.96 and - 0.94. Oleh itu, galasan tensil daripada jerami penanda boleh diguna sebagai penunjuk alternatif untuk menyatakan pereputan jerami padi dan untuk meramal K yang dibebaskan. Pemberian daripada MOP, CRS and UCRS ke tanah meningkatkan K yang dikumpul dalam tanaman jagung, kandungan jumlah K dan K tukarganti dalam tanah, tetapi peningkatan ini bergantung pada jangka waktu tumbesaran tanaman, kadar dan kedapatan K daripada baja yang diguna. Dibanding dengan MOP dan UCRS, penggunaan CRS adalah lebih baik dalam peningkatan pengambilan K, P dan Ca oleh tanaman dan menghasilkan tumbesaran tanaman yang lebih baik. Sebagai sumber K, kedapatan K daripada CRS adalah lebih cepat tersedia berbanding kedapatan K daripada UCRS dan MOP, tetapi pada 56 hari setepas ditanam (tahap pembungaan) dan pada kadar 360 mg K per pasu (90 kg K ha^{-1}), K tersedia untuk tanaman daripada tiga sumber baja K itu tidak berbeza, ia berkisar dari 90.48 ke 109.25 %. Galasan tensil daripada jerami penanda mungkin juga diguna sebagai penunjuk untuk meramal K yang dibebaskan daripada UCRS yang dimasukkan ke dalam tanah berdasarkan korelasi daripada galasan tensil dan kandungan K dalam jerami padi yang mereput selama pengkomposan. Tren galasan tensil kurang berguna sebagai penunjuk untuk meramal pengambilan K dan kandungan K dalam daun jagung.

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LOI	loss on ignition
TOC	total organic carbon
N	newtons
N	nitrogen
N	Normal
M	Molar
P	phosphorus
K	potassium
Ca	calcium
Mg	magnesium
CEC	cation exchange capacity
BD	bulk density
WHC	water holding capacity
CRS	composted rice straw
UCRS	uncomposted rice straw
MOP	Muriate of Potash
TSP	Triple Super Phosphate
GML	Ground Magnesium Limestone
nm	nano metre
MPa	Mega Pascal
dw	dry weight
dmw	dry matter weight

CHAPTER I

INTRODUCTION

Potassium fertilization is important in increasing and sustaining crop production, this is so because the natural K supply of most soils are often unable to meet the K needs of crops for high yield. At practical level, K fertilization can increase the efficient use of other nutrients by crops, particularly of N (Syers, 1998). However in many ASEAN countries, particularly in Indonesia and Malaysia, due to limitation of recoverable K reserves, the availability of inorganic K fertilizers depends heavily on import, the accompanying cost more often than not limit farmers in using K fertilizer. Recoverable K reserves in South and Southeast Asia account for only 7.5 % of the world K reserves (Sheldrick, 1985). Production of manufactured K_2O fertilizers in 1993 was 0.4 % of total world production and regional imports (excluding Japan) amounted to 3.6×10^6 tons K_2O, or 24 % of the world total (Maene, 1995).

The use of K fertilizer in many ASEAN countries is lower compared to N fertilizer (Christensen, 1995). Recommendations of K addition in most intensively irrigated rice domains are insufficient to replace K removal and as a result there is significant depletion of soil K at many sites (Dobermann *et al.*, 1996). Hence, it is crucial to manage or utilize other K source materials, such as crop residues, that are locally available as an alternative means to reduce the over dependency on inorganic K fertilizer. If properly used, returning crop residues to soil not only can reduce the use of inorganic (chemical) fertilizers but also has beneficial effect on the improvement of soil physical properties. Balanced fertilization through integrated nutrient supply and management is the most practical and viable technique, which holds the key to sustain yields and crop quality without adversely affecting the environment (Motsara, 1995).

With particular reference to Indonesia, rice (*Oryza sativa* L.) is the most important annual crop, yielding a large amount of rice straw annually. The yield of rice straw (dry basis) ranged from 3.96 to 5.32 tons ha^{-1}. The land area of rice based cropping system in 1993, for example, was about 11.01 million ha (Tjiptoningsih and Daulay, 1995). In some croplands, the rice crop is planted in rotation with corn (*Zea mays* L.) with sequence rotation rice-corn (Moentono and Fagi, 1992). At times, a major portion of the rice straw is removed from the field or considered as waste and burnt. Managing rice straw (in term of K source) is essential if sustainability is to be achieved with a small amount of inorganic K fertilizer addition. As an organic material, rice straw naturally has high levels of C and K, besides, other essential plant nutrients. About 80 % K taken up by rice crop is in the straw (De Datta and Gomez, 1982; Dobermann *et al.*, 1996).

Some researches have shown that returning rice straw to soil can contribute considerable K for crops, thus reducing the need of K fertilizer, maintains soil K level and increases the yield of crops (Gill and Sri Adiningsih, 1986; Cox and Uribe, 1992). However, there is lack of information about K supplying characteristic and crop available K from the rice straw. Information of this kind may help in the understanding of K cycling in soil--crop system. It may also lead to help in increasing efficient rice straw management and K fertilizer utilization.

This thesis reports a research consisting of two experiments on composting of rice straw as a means to promote the straw decomposition and a pot experiment using corn variety PJ-58 as test crop for K uptake planted on the Bungor series soil (Typic Paleudult) in a glasshouse. The objective of the first experiment was to study the change in tensile load of rice straw during rice straw composting, and its possibility to be used as an indicator for the state of decomposition and K released. While the objectives of second experiment were 1) to evaluate the crop available K from composted and uncomposted rice straw (CRS and UCRS) compared to that from Muriate of Potash (MOP) as standard K fertilizer and 2) to evaluate the use of tensile load of rice straw as an indicator to predict K released from rice straw incorporated in the soil, the crop K uptake and leaf K concentration.

CHAPTER II

LITERATURE REVIEW

Potassium Requirement and the Function in Crop Growth and Yield

Potassium (K) is an essential plant nutrient required in large amount, greater than any other nutrient with except to nitrogen, for metabolism and growth (Tisdale *et al.*, 1993; Plaster, 1997). Potassium has many biochemical and biophysical functions and plays an important part in stimulating photosynthesis; partitioning and storage of assimilate as well as in adaptation of crops to environmental stress. It is the major inorganic constituent in the cell vacuoles contributing to the osmotic and turgor potential of cells. It is an essential cation in all processes that are activated by proton pump (photosynthesis, phloem loading), and also needed for the activation of many enzymes (Beringer, 1982). The functions of K explain the importance of K for crop growth and yield. Sufficiency of K nutrition in crops has beneficial effect on the quality of a wide range of crops (Usherwood, 1985), especially in terms of improved protein quantity and quality; decrease the incidence of plant diseases (Huber and Arny, 1985).

Tropical tuber crops such as yam, cassava, sweet potato and coco yam, plantation crops such as sugarcane, coconut, tea, coffee, cocoa, rubber, oil palm and banana, and the cereal crops, particularly paddy, have high K requirements (Sekhon, 1982). In addition, most of vegetable crops such as peas, beans, spinach, sweet corn, cantaloupe, lettuce, onion, broccoli, brussels sprouts, tomato, carrots and celery also require high K to realize their high yields (Geraldson, 1985). Fast growing, early maturing cultivars have a higher rate requirement than late maturing ones (Halevy, 1976), and improved varieties of crops with greater potential for yield generally require higher supply of nutrients to realize their genetic yield potential (Cook, 1986). The high K requirement of crops, especially during their vegetative growth, demands a sufficient supply of this nutrient to achieve higher yield of the crops (Beringer, 1982).

Potassium in Soil

Potassium is present in igneous, sedimentary and metamorphic rocks; comprises about 2.5 % of the earth's crust in which it is the seventh most abundant element (Sheldrick, 1985). The lithosphere contains an average of 1.9 % K (Rich, 1968). However, the soil content an average of 1.2 % K, being lower than the lithosphere's, due to K lost through weathering. Organic soils are low in K because of their low mineral contents, and average value may be less than 0.03 % K. Young soils, having little weathering, have higher than average K contents (Barber, 1995). The available K in plants is generally only a small fraction of the total available of K in soil. The low fraction of K available is a consequence of both its inaccessibility and its relatively strong bonding in the 2:1 clay mineral structure (Lean and Watson, 1985).