UNIVERSITI PUTRA MALAYSIA

NITROGEN CONTRIBUTION OF PARASERIANTHES FALCATARIA TREE BIOMASS TO CORN (ZEA MAYS. L) PRODUCTION

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By

RICHARD CHINTU

Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of Agriculture Science in the Faculty of Agriculture Universiti Putra Malaysia

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DEDICATION

This thesis is dedicated to the entire human existence now, and time to come

Abstract of the thesis presented to the Senate of the Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Agriculture Science

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Chairperson: Professor Dr. Zaharah Abdul Rahman

Faculty: Agriculture

Tree legumes can be an important nitrogen (N) source for cereals in developing countries where little or no fertilizer is used due to prohibitive costs. *P. falcataria* biomass as a source of nitrogen for corn, was studied in a series of field and controlled experiments using ^{15}N labeling techniques. The aim of the study was to characterize the effect of biomass quality on nitrogen mineralization, and on N recovery from *P. falcataria* residues by corn.

It was hypothesized that mixing of residues of varying quality would alter residue (litter) quality and nitrogen mineralization. *P. falcataria* leaves were mixed with *P. falcataria* roots (*P. falcataria* mixture). Residue quality assessment was based on the index; (Polyphenol + Lignin)-to-N content. Litter quality was in the order of; *P. falcataria* leaves > *P. falcataria* mixture > *P. falcataria* roots, nitrogen and carbon (C) mineralization also followed the same sequence ($P < 0.05$), indicating that the potential of residues to increase soil inorganic N depends on their quality.

P. falcataria leaves including mixture treatments significantly ($P<0.05$) mitigated soil acidity while *P. falcataria* roots alone did not. Thus, there is a potential benefit of residues as 'lime' in cropping systems.

Leaves under humid tropical conditions decomposed rapidly causing an initial transitory increase in soil inorganic N, then substantial NO_3-N leaching from 30 to 60 days after application. Significant amounts of Ca^{++}, Mg^{++}, and K^{+} were leached beyond the top 20 cm soil profile only after 60 days.

There is need to strategically mix residues of contrasting quality, to regulate N release and reduce leaching while increasing soil inorganic N under field conditions. The potential of the ^{15}N indirect and direct labeling methods to estimate N- cycling from tree residues was similar ($P<0.05$). Corn recovered more N from *P. falcataria* roots than from *P. falcataria* leaves.

Data on corn produced under field conditions indicated that, the use of residues in combination with an inorganic N source, as opposed to the sole use of either of them, seems a more effective management strategy for improving N use efficiency, including mitigating soil acidity.

Abstrak tesis yang dikemukakan kepada Senat Universiti Malaysia sebagai memenuhi keperluan untuk penganugerahan ijazah Master Sains Pertanian

SUMBANGAN NITROGEN DARIPADA BIOJISIM POKOK *PARASERIANTHES FALCATARIA* KEPADA PENGELUARAN JAGUNG (*ZEA MAYS* .L)

By
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January 2002

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Pokok kekacang boleh menjadi sumber nitrogen yang penting kepada bijirin di negara-negara membangun di mana tiada atau kurang penggunaan baja kerana kos yang tinggi.

Biojisim *P. falcataria* sebagai sumber N untuk jagung telah dikaji dalam beberapa siri kajian ladang dan terkawal menggunakan teknik penglabelan ^{15}N. Tujuan kajian ialah untuk mencirikan kesan kualiti biojisim ke atas pemineralan N dan pengambilan N dari sisa *P. falcataria* oleh jagung.

Ini berdasarkan hipotesis bahawa campuran sisa-sisa pelbagai kualiti akan mengubah kualiti sisa dan pemineralan N. Daun-daun *P. falcataria* dicampur dengan akar (campuran *P. falcataria*). Kualiti sisa dinilai berdasarkan indeks nisbah kandungan polifenol+lignin kepada N. Kualiti sisa adalah mengikut turutan daun *P. falcataria*>campuran *P. falcataria*>akar *P. falcataria*, dan pemineralan nitrogen dan carbon juga mengikut turutan yang sama ($P<0.05$), menunjukkan potensi sisa untuk meningkatkan mineral N tanah bergantung kepada kualitinya. Rawatan daun *P.*

falcataria dan campuran *P. falcataria* mengurangkan keasidan tanah dengan bererti ($P<0.05$) manakala akar *P. falcataria* sahaja tidak. Ini menunjukkan potensi sisa sebagai 'bahan kapur' dalam sistem pertanian.

Di kawasan tropika lembap daun akan mereput dengan cepat dan menyebabkan peningkatan sementara N tak organik dalam pada, diikuti dengan larutlesap N yang banyak pada hari ke 30 hingga 60 selepas rawatan. Penglarutlesapan Ca^{++}, Mg^{++}, dan K^{+} yang bererti melampaui paras 20 cm profil tanah hanya berlaku selepas 60 hari.

Strategi pencampuran sisa berbeza kualiti adalah perlu untuk mengawalatur pembebasan N dan mengurangkan proses larutlesap sambil meningkatkan mineral N tanah di lapangan. Potensi kaedah penglabelan ^{15}N secara langsung dan tidak langsung untuk menganggarkan kitaran N dari sisa pokok adalah sama ($P<0.05$). Jagung mendapat lebih N dari akar *P. falcataria* berbanding daun *P. falcataria.*

Data pengeluaran jagung di bawah keadaan lapangan menunjukkan bahawa penggunaan gabungan sisa dan sumber N tak organik, berbanding dengan penggunaan hanya sisa atau N tak organik sahaja, merupakan satu strategi pengurusan yang lebih berkesan untuk meningkatkan kecekapan penggunaan N, termasuklah mengurangkan keasidan tanah.

ACKNOWLEDGMENTS

As a preamble to this report, I quote the African proverb 'umweo wa bantu walala mu matwi' which literally translated reads; 'human life lies in the ears' but the moral or broader meaning of it as taught to me by my late grand mother is that 'the potential of human beings to survive depends on their ability to listen and learn'.

My mentors, my sponsors and I, will only feel repaid for this work if, either the scientific facts or ignorance highlighted in this report, in a minute or major way, contribute to the advancement of knowledge for the benefit of the present and future generations world-over.

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I have tremendously searched my English vocabulary, but all in vain, for the most suitable words to use to acknowledge the tremendous support and assistance rendered to me and to my family by my work mates and friends, individually or collectively, during my long absence from home.

To my loving and beloved family that missed my much needed presence at home for a whole period of two years, I say that, I know very well that home is the best place to be, but at times we have to get away if only to better our selves professionally so as to contribute more meaningfully to the extremely needy economy of our mother land, Africa.

I certify that an Examination Committee met on 8th January 2002 to conduct the final examination of Richard Chintu on his Master of Agriculture Science thesis entitled "Nitrogen Contribution of *Paraserianthes falcataria* Tree Biomass to Corn (*Zea mays*. L) Production" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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Date: 14 MAR 2002

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

RICHARD CHINTU

Date: 8th January 2002

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CHAPTER I

INTRODUCTION

Back-ground

Most farmers in the tropics face the critical problem of ever declining crop yields due to nutrient mining arising from continuous cropping without adequate replenishment of the depleted nutrients. In most cases inorganic fertilizers are either insufficiently used or not used at all because of financial constraints and distribution problems. Nitrogen is known to be the most limiting nutrient to crop production in the tropics. However, organic inputs such as green manures and litter from legumes have shown some potential in mitigating soil N deficiency, though for various reasons, N use efficiency remains low in most cases.

In agroforestry land-use systems, organic inputs in terms of above ground (fresh leaves, twigs and dry litter) and below ground (dead and live root) biomass from N rich tree legumes play a significant role in the supply of N to crops. While literature on most agroforestry cropping systems has dealt much on N contribution of tree above ground biomass to crop, little documentations are available on tree below ground biomass N contribution to crop productivity. One of the basic reasons for poor documentation of the role of roots in agroforestry systems is that, quantitative root studies in the field are notoriously difficult and cumbersome, especially when time and labour aspects are fully taken into account (Schroth, 1999).

In this study, less laborious methods of direct and indirect ^{15}N isotope labeling of plants and plant residues were used in an attempt to quantitatively separate the below- and above-ground biomass N contribution of *P. falcataria* to corn grain crop in agroforestry cropping systems.

The study was aimed at providing some insights into appropriate strategies for modifying the existing agroforestry practices and systems in order to optimize their productivity as well as their overall economic viability. For instance, it was assumed that, if N contributed by roots alone, can meet crop N requirement, then above-ground biomass would be spared for a range of other optional uses or technologies such as biomass transfer for either fodder or soil fertility improvement.

Justification

Nitrogen plays a key role in plant nutrition. It is the mineral required in greatest quantity by cereal crops and is the nutrient that is most often deficient in tropical soils. As a result of its critical role and low supply, N resource management is an extremely important aspect in crop production (Novoa *et al.*, 1981). Fertilizer use in many small holder, resource poor tropical agricultural systems remain insufficient to meet crop N demand as well as to sustain soil fertility due to critical financial constraints (Buresh *et al.*, 1998). Researchers (Kwesiga and Coe, 1994; Kwesiga *et al.*, 1999) suggested deliberate inclusion of N_2-fixing tree legumes in the tropical production systems in order to increase N availability to crops. The potential soil fertility benefits from the use of leaves of such tree legumes as *G. sepium* and *S. sesban* in agroforestry cropping systems has been well acknowledged by various authors (Wade *et al.*, 1983; Zaharah *et al.*, 1996; Buresh *et al.* 1997; Kwesiga *et al.*, 1999). Mafongoya *et al.* (1997a and 1998a) and also Buresh (pers. comm.) attributed the increase in maize grain yield under improved fallow management to increase in soil inorganic N due to decomposition of the incorporated leaves and twigs.

Periodic pruning of above ground biomass (shoots) is a common management practice in agroforestry systems such as alley cropping, biomass transfer and improved fallow systems that integrate coppicing legume tree species. The practice does not only promote leaf biomass production and recycling of N from the leaves, but it also induces root N turn over (i. e. some amount of fine roots die, decompose and eventually mineralize and enhance soil inorganic N availability). Lehmann *et al.* (1998) concluded from a review of literature that the ratio of live-to-dead roots decreased when the trees were pruned, suggesting root biomass shedding. Bashir *et al.* (1998) reported that, about 20 to 50% of root residues from trees and shrubs in a tropical self regenerating fallow is converted to soil humus while only 10 to 20 % of above ground litter is converted into soil humus.

According to Palm (1995) and Giller *et al.* (1995) crop nitrogen recovery from the incorporated prunings range between 10 to 20%. However, there is an indication that root N contribution to crop in agroforestry systems can be substantial since, below ground biomass accumulation by tree roots could be considerably high, in the order of 3 to 6 Mg ha^{-1} $year^{-1}$ (Sanchez, 1995). Mineralization rate of organic matter is one of the major factors that influence N availability to crops. Synchrony or asynchrony of N demand by the crop, with N supply from an organic source also depends on the rate of mineralization and timing of application of the organic source. A green house study by Mafongoya *et al.* (1997a) highlighted three important factors that influence mineralization of organic residues: Chemical composition (i.e. residue quality), cultural practices (i.e. method, timing and rate of application) and soil properties. However, the environmental or microclimatic conditions (temperature and moisture) may override all the above factors. When physical and environmental factors are not limiting, residue quality plays an important role in regulating decomposition rate (Buresh *et al.*, 1998).

This study attempted to address the following issues which were identified as crucial knowledge gaps with regards to the use of *P. falcataria* above and below ground biomass as a source of N for crop production.

- Residue quality i.e. N, polyphenol and lignin content of the above- and below-ground biomass.
- N mineralization rates from tree leaf and root components, individually and in mixture.
- Above- and below-ground biomass production of *P. falcataria* tree
- N recovery from *P. falcataria* residues by the crop (corn).
- Soil inorganic N and soil pH dynamics as affected by the tree or its components once integrated in the cropping system.

Hypotheses

The hypotheses for this study were as follows:

- Once *P. falcataria* above ground biomass is harvested, the corresponding unexcavated below ground biomass will have a nutrient release pattern in close synchrony with the nutrient demand of the associated corn, leading to a relatively higher N use efficiency in agroforestry cropping systems.

- N mineralization from fresh *P. falcataria* leaves decomposing under humid tropical field conditions would be high, with potential risks of rapid N loss by leaching.

- Combining residues of varying or contrasting qualities alters or regulates rate of mineralization.

- Sustainable, cost effective soil fertility management options, leading to high and stable soil N status and recovery rates, will result from land-use strategies that integrate minimal inorganic farm inputs with readily available organic resources.

General Objective:

The general objective was as follows:

- To show the effects of above and below ground biomass of *P. falcataria* on soil inorganic N availability to crop.

Specific Objectives

The specific objectives were:

(1) To determine the quality of *P. falcataria* leaves and roots separately and when mixed;

(2) To characterize N and C mineralization of *P. falcataria* leaves and roots incubated individually and in mixture under controlled or uncontrolled conditions in an acidic Ultisol;

(3) To determine the soil inorganic N and soil pH dynamics as affected by *P. falcataria* integrated in cropping systems;

(4) To assess crop recovery rates of the N mineralized from the above- and below-ground biomass components of *P. falcataria;*

(5) To compare the ^{15}N direct and the indirect labeling techniques as tools of estimating N cycling from leaf residues of trees in agroforestry cropping systems.

Why the *P. falcataria* Option?

P. falcataria is a tree legume which belongs to the genus *Albizia*. It is indigenous to Indian subcontinent, Southeast Asia and monsoon areas of Australia (Lowry, 1989). It also adapts well to most areas of the wet tropics and it is a species of major importance due to its wide range of uses (Lowry, 1989). The well known attributes of the *P. falcataria* include:

- Provision of fodder
- Bearing of edible fruits
- Provision of wood for timber and fuel (can accumulate as much as 5m^3 of wood biomass ha^{-1} yr^{-1} - Pradhan and Dayal, 1981)
- Potential source of leaf litter for manuring (can shed 5 tons of leaf biomass ha^{-1} yr^{-1} -Pradhan and Dayal, 1981)
- Provides an array of traditional medicines (Dastur, 1951).