



UNIVERSITI PUTRA MALAYSIA

***INTERCROPPING OF CORN (*Zea mays* L.) WITH GROUNDNUT
(*Arachis hypogea* L.) AND BAMBARA NUT (*Vigna subterranea* L.)
TO INCREASE PROTEIN CONTENT OF COMBINED FORAGE***

DAUDA MUSTAPHA BELEL

FP 2016 42



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By

DAUDA MUSTAPHA BELEL

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfillment of the Requirements for the Degree of Doctor of Philosophy**

September 2016

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DEDICATION

My children



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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

INTERCROPPING OF CORN (*Zea mays* L.) WITH GROUNDNUT (*Arachis hypogea* L.) AND BAMBARA NUT (*Vigna subterranea* L.) TO INCREASE PROTEIN CONTENT OF COMBINED FORAGE

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September 2016

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Faculty : Agriculture

Forage corn has been used as a feed resource for ruminant but it is low in crude protein content such that animals have to be supplemented with protein sources. In order to increase the protein in corn forages, three corn intercropping experiments were conducted with two grain legumes: bambara nut (*Vigna subterranea* L. Verdc) and groundnut (*Arachis hypogea* L.) to evaluate their potential to increase forage quality.

In the first experiment, six introduced bambara nut landraces from Nigeria (Bambwus, Kurvu, KwadaZwalang, Tanyanyi, IndaraAyaghayagha and Karamagdanda) and one from Thailand (Songkla 1) were evaluated. The Songkla 1 variety has been grown in Malaysia over the last 15 years while the Nigerian landraces are newly introduced. The objective was to evaluate whether the Nigerian landraces could perform as well or better than the Songkla 1 variety in the Malaysian environment. There were significant differences ($p \leq 0.05$) among the introduced African landraces and the adapted Songkla 1 variety. Kurvu recorded a higher forage dry matter ($2,343 \text{ kg ha}^{-1}$) and pod yield ($1,349 \text{ kg ha}^{-1}$). Harvest index was higher at 46.8% for Bambwus. In general, the introduced African landraces showed a better performance than the adapted Songkla1 variety and hence some of these landraces could be selected for planting in the tropical humid climate of Malaysia. Bambwus was superior to other varieties and was ranked first and was selected for inclusion in the subsequent corn/legume intercropping experiments.

In the second experiment, corn was intercropped with bambara nut and groundnut at a 1:1 ratio to determine the contribution of each legume towards the yield and quality of the combined forage. The experiment involved six treatments (sole corn with nitrogen, sole corn without nitrogen, sole groundnut, sole bambara nut, corn/bambara nut intercrop and corn/groundnut intercrop) replicated three times in a randomized complete block design. Nitrogen fertilizer was not applied to all treatments except for the first treatment. Intercropping significantly ($p \leq 0.05$) increased the growth of corn crop and suppressed both bambara nut and groundnut.

A higher yield was obtained from nitrogen-fertilized corn. However, intercropping showed its advantage through 36% and 59% better land equivalent ratio (LER) in intercrop than in monocrop for corn/bambara nut and corn/groundnut respectively. The relationship between corn and the legumes was synergistic in nature as shown by relative yield total which was 1.36 for corn-bambara nut and 1.59 for corn-groundnut. Digestibility was higher in the corn/legume forage (57.5%) compared to sole corn (51.8%). Similarly, corn intercropped with bambara nut and groundnut had higher protein content (10.8 and 12.9%) compared to sole corn (8.21%). Groundnut was a better legume for intercropping with corn than bambara nut in terms of yield but bambara nut was selected for the next study in order to further understand its performance in humid tropical environment.

In the third experiment, corn was intercropped with bambara nut landrace Bambwus in a randomized complete block design using different planting patterns based on the ratio of corn/bambara nut as follows (C=Corn, B=Bambara, N=Nitrogen): C4:B0, C4:B0+N, C3:B1, C2:B2, C1:B3, C0:B4. The crop growth rate, leaf chlorophyll and total leaf area were significantly higher among the intercrops compared to monocrops. Total dry matter yield was similar in all combinations. Sole corn had 73% neutral detergent fiber (NDF) which was higher than in the intercrops except C1:B3. Corn/bambara nut combinations ratios also differed significantly in NDF and acid detergent fiber (ADF). Protein in sole bambara nut was 14.8%. Among the combinations, crude protein was highest in C1:B3 (17.3%). Crude protein in sole corn was 8.52%. Lignin was highest in combinations with more bambara nut with sole bambara nut having 4.92% lignin. The planting patterns all gave a land equivalent ratio (LER) higher than 1.00 which indicated the benefit of intercropping. Aggressivity index indicates that corn was more aggressive than bambara nut in their competition. For improvement of overall forage quality it is recommended that bambara nut be planted as an intercrop with corn at the ratio of 1 corn to 3 bambara nut. The Nigerian landrace Bambwus should be used in place of Songkla 1 because of its relatively superior performance.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

**PENANAMAN SELINGAN ANTARA JAGUNG DENGAN KACANG
TANAH DAN KACANG BAMBARA UNTUK MENINGGIKAN
KANDUNGAN PROTEIN BAGI FORAJ CAMPURAN**

Oleh

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Foraj jagung telah lama digunakan sebagai sumber makanan bagi haiwan ternakan, namun kandungan protein kasar yang rendah mengakibatkan haiwan ternakan perlu diberi makanan protein tambahan. Bagi meningkatkan kandungan protein dalam foraj jagung, tiga eksperimen menggunakan kaedah penanaman selingan antara jagung dengan dua tanaman kekacang. Kacang bambara (*Vigna subterranea* L. Verdc) dan kacang tanah (*Arachis hypogea*) yang merupakan salah satu kaedah tanaman lestari demi meningkatkan tahap protein dalam foraj campuran.

Eksperimen pertama membuat penilaian terhadap enam jenis kacang bambara dari Nigeria (Bambwus, Kurvu, KwadaZwalang, Tanyanyi, IndaraAyaghayagha, and Karamagdanda) dan satu varieti dari Thailand (Songkla 1). Varieti Songkla 1 telah ditanam di Malaysia semenjak 15 tahun dahulu manakala varieti Nigeria baru diperkenalkan. Keputusan menunjukkan perbezaan yang signifikan ($p \leq 0.05$) antara enam jenis kacang bambara (varieti dari Afrika) berbanding varieti Songkla 1. Kurvu mencatatkan hasil berat kering ($2,343 \text{ kg ha}^{-1}$) dan hasil kantung kacang ($1,349 \text{ kg ha}^{-1}$) yang paling tinggi. Indeks hasil tertinggi dicatatkan oleh Bambwus iaitu sebanyak 46.80%. Secara keseluruhannya, varieti-varieti dari Afrika menunjukkan hasil yang lebih memberansangkan daripada varieti Songkla1 dan sebahagian daripada varieti tersebut boleh dipilih untuk penanaman di iklim tropika lembab yang terdapat di Malaysia. Bambwus dinilai menduduki tempat pertama dan telah dipilih untuk tujuan penanaman selingan dengan tanaman jagung.

Eksperimen kedua, merupakan penanaman selingan antara jagung dengan kacang bambara dan kacang tanah dengan nisbah 1:1 bagi menentukan sumbangan tanaman kekacang terhadap hasil dan kualiti foraj campuran. Eksperimen ini melibatkan enam rawatan (jagung tunggal dengan baja nitrogen, jagung tunggal tanpa baja nitrogen, kacang tanah tunggal, kacang bambara, penanam selingan jagung/bambara dan penanam selingan jagung/kacang tanah) dalam tiga replikasi. Baja nitrogen hanya digunakan untuk rawatan yang pertama, rawatan yang lain tidak diletakkan baja nitrogen. Keputusan menunjukkan penanam selingan telah

meningkatkan pertumbuhan tanaman utama iaitu jagung dan melebihi pertumbuhan tanaman selingan tanaman kekacang sama ada bagi kacang bambara mahupun kacang tanah. Hasil tertinggi diperolehi oleh jagung dengan rawatan baja nitrogen. Walau bagaimanapun, penanaman selingan jagung/bambara dan penanam selingan jagung/kacang tanah menunjukkan peningkatan nisbah setara tanah (LER) lebih baik daripada penanam jagung tunggal dengan masing-masing sebanyak 36% dan 59%. Pola persaingan antara tanaman utama dan tanaman gandingan yang diukur oleh jumlah hasil relatif (LER) menunjukkan bahawa perhubungan sinergi berlaku antara jagung dan tanaman kekacang iaitu kacang bambara menunjukkan LER 1.36 dan kacang tanah 1.59. Berlaku juga peningkatan terhadap nilai pencernaan oleh campuran jagung/kekacang berbanding jagung tunggal (57.5% bagi campuran berbanding 51.8% bagi jagung tunggal. Peningkatan kandungan protein dapat dilihat juga dengan penanaman selingan jagung dengan kacang bambara dan kacang tanah kerana kandungan protein lebih tinggi daripada penanaman jagung tunggal (10.8% dan 12.9% dalam penanaman campuran berbanding 8.21% dalam penanaman jagung tunggal). Kacang tanah adalah legum yang lebih baik untuk intercropping dengan jagung dari bambara nut dari segi hasil tetapi bambara nut telah dipilih untuk kajian akan datang untuk memahami lagi prestasinya dalam persekitaran tropika lembap.

Eksperimen ketiga adalah penanaman selingan antara jagung dan kacang bambara 'Bambwus' dengan beberapa pola penanaman yang berdasarkan kepada nisbah antara jagung dan kacang bambara iaitu seperti berikut (C=Jagung, B= Kacang bambara, N=Nitrogen): C4:B0, C4:B0+N, C3:B1, C2:B2, C1:B3, C4:B0. Keputusan menunjukkan kadar pertumbuhan tanaman, kandungan klorofil daun dan jumlah luas daun adalah lebih tinggi dalam penanaman gabungan jagung dan kacang bambara berbanding penanaman jagung tunggal. Hasil berat kering adalah sama antara semua kombinasi. Jagung tunggal mempunyai 73% fiber detergen neutral (NDF) iaitu lebih tinggi daripada tanaman campuran kecuali C1:B3. Kombinasi jagung/bambara dengan nisbah berbeza juga menunjukkan perbezaan signifikan dalam NDF dan serat detergen asid (ADF). Protein dalam tanaman kacang bambara tunggal adalah 14.8%. Kandungan protein adalah tertinggi dalam kombinasi C1:B3 (17.3%). Protein kasar dalam tanaman jagung tunggal adalah 8.52%. Kandungan lignin meningkat dengan peningkatan nisbah bambara dan bambara tunggal mempunyai kandungan lignin tertinggi sebanyak 4.92%. Semua tanaman campuran memberikan nisbah persamaan tanah (LER) lebih tinggi daripada 1.00 menunjukkan manfaat tanaman campuran. Aggressivity indeks menunjukkan bahawa jagung adalah lebih agresif berbanding kacang bambara. Untuk meningkatkan kualiti foraj, nisbah campuran yang disyorkan ialah 1 bahagian jagung kepada 3 bahagian bambara. Jenis bambara yang disyorkan ialah jenis Bambwus dari Nigeria yang telah menunjukkan prestasi lebih tinggi daripada Songkla1 yang kini digunakan di Malaysia.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
ANOVA	Analysis of Variance
AYL	Actual Yield Loss
CB	Corn/ Bambara nut
CFFRC	Crops for the Future Research Centre
CG	Corn/Groundnut
CGR	Crop Growth Rate
CP	Crude Protein
CR	Competitive Ratio
CTAB	Cetyl trimethylammonium bromide
CV	Coefficient of Variation
C0:B4	Pure stands of Bambara nut
C1:B3	Two Row Corn: Six Rows Bambara nut
C2:B2	Four rows Corn: Four Rows Bambara nut
C3:B1	Six Rows Corn: Two Row Bambara nut
C4:B0	Pure stands of corn without nitrogen fertilizer
C4:B0+N	Pure stands of corn with nitrogen fertilizer
DF	Degree of Freedom
DMD	Dry Matter Digestibility
DMY	Dry Matter Yield
EDTA	Disodium ethylene diamine tetra acetate
FAOSTAT	Food and Agriculture Organization Statistics
HI	Harvest Index

ICRISAT	International Cereal Research Institute for Semi-Arid Tropics
LAI	Leaf Area Index
LC	Leaf Chlorophyll
LER	Land Equivalent Ratio
LSD	Least Significant Difference
MOP	Muriate of Potash
NDF	Neutral Detergent Fiber
ns	Not Significant
RCBD	Randomized Complete Block Design
RSR	Root to Shoot Ratio
RY	Relative Yield
RYT	Relative Yield Totals
SB	Sole bambara nut
SG	Sole groundnut
TLA	Total Leaf Area
TSP	Triple Super Phosphate
WAS	Weeks After Sowing

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CHAPTER 1

INTRODUCTION

The cultivation of cereal and legumes in a compatible combination is popular among subsistence farmers in the tropics. This is with the ultimate aim of producing food grains for immediate family consumption, leaving out the remaining vegetative leaf litter and straw as residue for livestock grazing on the farm. Intercropping of legumes and cereals at a given proportion is aimed at improving the quality and yield of forage (legumes and cereals) in order to provide better livestock feed.

The expected increase in demand for animal products makes it critical to develop forage with higher protein content. Legumes fix nitrogen in the soil which help to improve fertility of such soil and thus increase the nitrogen and protein levels in crops. Nowadays, attention is focused on providing a quality grazing pasture of high protein content for livestock in order to boost both quality meat and milk production. Protein is a major constituent in cell multiplication and bodybuilding in animals and the quality forage required for the growing nutritional needs of the livestock has to be sourced through corn-legume intercropping. Intercropping of cereal and legume gives a balanced and high forage protein due to substrate transfer during this interaction.

Many countries of the world have now achieved productivity in crops through intercropping (Francis, 1986). The system has shown to be more effective than monocropping as it helps to produce surplus food from a less expanse of land with minimal impact on the environment.

Most studies on intercropping have concentrated on the useful and sustainable system, i.e. on the legume-cereal intercropping (Fusuo and Li, 2003). Intercropping plays a dynamic role in subsistence food production in both advanced and emerging countries (Adeoye *et al.*, 2005). Several researches have been reported on intercropping (Mandal *et al.*, 1990; Brintha and Seran, 2009; Ijoyah, 2012), mostly focusing on cereal-legume intercrops (Ofori and Stern, 1987; Hugar and Palled, 2008) and all proved successful.

Intercropping of cereal and legume is a good combination which gives high energy and protein which could provide good source of feed for livestock. Certain legumes such as bambara nut has not been grown in the humid tropics under different intercropping patterns with corn. Bambara nut is a legume that was recently introduced to Asia (and Malaysia) and it presents a great potential for improved food production on tropical marginal soils (CFFRC, 2012). In Malaysia, the Crops for the Future Research Center (CFFRC) located in the University of Nottingham adopted it as its mandate crop in the underutilized crops program. The crop has several natural agronomic advantages including: high nutritional value, drought resistance, resilience to high temperatures and is fit for marginal soils where other leguminous crops cannot grow. Hence, there is a need to evaluate the performance of different landraces to

identify a suitable choice for intercropping with corn for the improvement of forage production in the humid tropics. The world's need for an improved supply of quality food and feed demands that crops be grown outside their usual growing environment, especially hardy crops that can adapt to a wide range of ecological conditions.

The majority of ruminant livestock in tropical countries are raised on natural pastures which decline rapidly in quality due to ageing in the dry seasons. In order to reduce the nitrogen fertilizer requirement as well as to improve quality through the increase of protein in the feed, planting corn with grain legumes may be a solution. The understanding of these critical needs, especially from different grain legume crops in a suitable combination with corn for high protein forage should be explored. Underutilized grain legume forages are potential sources of supplement in ruminant livestock diet.

Different planting patterns for cereal-legume intercropping have been practiced by many researchers and farmers and the yield advantage of intercropping has not been so marked in several situations possibly due to the use of supra-optimal plant population proportions and in some cases, to the use of sub-optimal population proportions for component crops. The use of different combination ratio between corn and the legume to ascertain the optimal yield and forage value of the mixture becomes eminent. Different planting patterns and crop composition need to be optimized to obtain the best yield and forage quality in a corn-legume intercrop. The cropping system of the humid tropical environment could be enriched by including the bambara nut legume in intercropping through different planting patterns.

The main objective of this research is to intercrop corn with groundnut and bambara nut to increase the protein content of combined forage. The following are the specific objectives of the study:

- i) To evaluate the performance of different landraces of bambara nut and to select the best landrace for incorporation into a corn-legume intercropping.
- ii) To evaluate the performance of two different legumes (bambara nut and groundnut) in intercropping and select the better legume for incorporation into the corn-legume intercropping system
- iii) To assess the yield and forage quality of corn and legume in different intercrop ratios.

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