UNIVERSITI PUTRA MALAYSIA

INTERCROPPING OF CORN AND LEGUMES WITH APPLICATION OF CHICKEN MANURE AND CROP COMBINATION RATIOS TO INCREASE YIELD AND QUALITY OF CORN-LEGUME FORAGE

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By

ALI BAGHDADI

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

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Specially dedicated to:

My beloved wife Maryam

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

INTERCROPPING OF CORN AND LEGUMES WITH APPLICATION OF CHICKEN MANURE AND CROP COMBINATION RATIOS TO INCREASE YIELD AND QUALITY OF CORN-LEGUME FORAGE

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Chair: Associate Professor Mohd Ridzwan A. Halim, PhD
Faculty: Agriculture

Corn silage is an important feed for intensive ruminant production but the growing of corn has relied heavily on the use of chemical fertilizer. Experiments were conducted to determine the appropriate technology of corn-legume intercropping with supplemental use of chemical, organic manure and biofertilizer. In experiment one, three species of legumes: stylo (Stylosanthes guianensis), soybean (Glycine max) and mungbean (Vigna radiata) were intercropped with corn to select the best legume species to use for intercropping. Results indicated that corn-soybean intercropping gave the highest mixed forage dry matter (14.10 t/ha) compared to corn-mungbean (13.22 t/ha) and corn-stylo intercropping (8.77 t/ha) ($p<0.05$). Corn-soybean intercropping produced good quality feed in terms of the nutritive quality of forage and volatile fatty acids (VFA) of silage. Soybean contributed to increased crude protein (CP) in mixed corn-soybean forage (14.11%) in comparison with sole corn crop (10.05%), corn-mungbean (13.14%) and corn-stylo (11.28%) ($p<0.05$). Corn-soybean intercropping gave the highest forage protein yield (1990 kg/ha) ($p<0.05$) in comparison with corn monocrop (1415 kg/ha) and other corn-legume intercropped treatments. Higher level of CP, CP yield, leaves chlorophyll, leaf area index (LAI) and plant maturity of soybean than other legumes hence higher forage quality and DM of corn-soybean. In the second experiment, corn-soybean combinations of 75:25, 50:50 and 25:75 in addition to monocrops of corn and soybean were evaluated. The ratio of 75:25 and 50:50 recorded DM yields similar to those of monocropped corn (14.77 t/ha). Relative yield total (RYT) values of intercropping were higher than that of monocrop corn and soybean. Mixtures with 50:50 combination ratio had higher mean RYT values (1.15) ($p<0.05$) than the other ratios. Land equivalent ratio (LER) increased with corn-soybean intercropping and the highest total LER value was recorded with 50:50 ratio (1.13). Forage quality in terms of CP (75:25 ratio 12.75%, 50:50 ratio 13.73% and 25:75 ratio 14.68%) was improved by intercropping due to higher nitrogen availability for corn in intercropping compared with its sole crop (10.83% CP). Combination ratio of 50:50 gave higher protein yield (1886.45 kg/ha) than other crop combination ratio. The third experiment was carried out to evaluate effects of 10 types of fertilizer on corn-soybean forage yield and quality. Chemical fertilizer (NPK) gave significantly higher yield and quality of forage compared to organic and biofertilizer ($p<0.05$). Combining chemical fertilizers with chicken manure in a 50:50 ratio resulted in similar dry matter yield with the 100% NPK

treatment. This might be attributed to the gradual release of essential nutrient from chemical and chicken manure (CM) fertilizer as required by the plants at all growth time. Combinations of NPK and CM resulted in increased plant height; crop growth rate (CGR) and LAI compared to CM alone but was similar to 100% NPK application. Similarly, CP content was not significantly different among 100% NPK (14.48%) and 50% CM+50% NPK (14.55%). Treatments with application of biofertilizer and combination of biofertilizer with NPK or CM treatments gave higher values of ARA compared to sole chemical and sole organic manure fertilizers. Overall, evidences recorded from this study prove that corn-soybean intercrops could increase forage quantity and quality, produce higher total protein yield, decrease requirements for protein supplements and chemical fertilizer compared to the corn monoculture with a 50:50 corn-soybean combination ratio and combination of chicken manure and chemical fertilizer.

Abstraktesis yang dikemukakankepadaSenatUniversiti Putra Malaysia
sebagaimemenuhikeperluanuntukijazah Doktor Falsafah

PENANAMAN SELINGAN JAGUNG DAN POKOK KEKACANG DENGAN APLIKASI BAJA TAHI AYAM DAN NISBAH KOMBINASI TANAMAN UNTUK MENINGKATKAN HASIL DAN KUALITI FORAJ JAGUNG-KEKACANG

Oleh

ALI BAGHDADI

Julai 2015

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Silaj jagung adalah makanan ternakan yang penting bagi pengeluaran ternakan ruminan. Walau bagaimanapun, pembajaan dalam penanaman jagung sangat bergantung kepada penggunaan baja kimia. Beberapa eksperimen telah dijalankan bagi menentukan teknologi yang sesuai untuk penanaman selingan antara jagung dengan kekacang dan kaedah pembajaan menggunakan baja kimia, baja organik dan baja bio. Bagi eksperimen pertama, tiga spesies kekacang iaitu stylo (Stylosanthes guianensis), soya (Glycine max) dan kacang hijau (Vigna radiata) telah diuji bagi menentukan spesies terbaik untuk digunakan dalam penanaman selingan bersama jagung. Hasil kajian mendapati tanaman selingan jagung dengan soya telah meningkatkan berat kering foraj campuran (14.10 t/ha) berbanding tanaman selingan jagung dengan kacang hijau (13.22 t/ha) dan tanaman selingan jagung dengan stylo (8.77 t/ha($p<0.05$). Berdasarkan keputusan eksperimen ini, tanaman selingan jagung dengan soya telah dibuktikan dapat menghasilkan foraj yang berkualiti tinggi. Soya telah menyumbang kepada kenaikan protein kasar (CP) foraj (kandungan CP 14.11%) berbanding foraj dari tanaman jagung tunggal (10.05%), tanaman selingan jagung dengan kacang hijau (13.14%) dan tanaman selingan jagung dengan stylo (11.28%) ($p<0.05$). Penanaman selingan jagung dengan soya adalah yang terbaik kerana telah menunjukkan peningkatan terhadap hasil protein foraj iaitu sebanyak 1990 kg/ha berbanding tanaman jagung tunggal (1415 kg/ha) dan kombinasi tanaman selingan yang lain. Paras CP, hasil CP, klorofil daun, luas permukaan daun LAI) yang lebih tinggi dan kematangan tanaman soya yang lebih tinggi berbanding legum lain, menjadikan kualiti foraj dan DM jagung-soya yang lebih tinggi. Dalam eksperimen kedua, beberapa kombinasi nisbah jagung dengan soya telah dijalankan bagi menentukan kombinasi terbaik untuk melaksanakan penanaman selingan. Kombinasi tersebut ialah 75:25, 50:50 dan 25:75. Penanaman jagung tunggal dan penanaman soya tunggal digunakan sebagai rawatan kawalan. Kombinasi tanaman selingan telah memberikan kesan yang bererti kepada sifat-sifat fisiologi pokok, berat kering hasil, dan kualiti nutrient dalam foraj dan silaj. Nisbah jagung:soya 75:25 dan 50:50 direkodkan memiliki berat kering hasil yang menyamai berat kering hasil dari penanaman jagung tunggal (14.77 t/ha). Jumlah hasil relatif (RYT) bagi penanaman selingan adalah lebih tinggi berbanding tanaman jagung tunggal dan tanaman soya tunggal. Kombinasi nisbah jagung:soya 50:50 memberikan

nilai RYT paling tinggi (1.15) ($p<0.05$) daripada kombinasi nisbah yang lain. Nisbah setara tanah (LER) juga telah meningkat bagi penanaman selingan dan LER tertinggi (1.13) direkodkan daripada nisbah jagung:soya 50:50. Bagi penentuan kualiti foraj, protein kasar foraj daripada penanaman selingan adalah lebih baik daripada penanaman secara tunggal kerana kedapatan nitrogen untuk jagung lebih tinggi dalam penanaman selingan. Nilai protein kasar foraj bagi nisbah 75:25 ialah 12.75%, nisbah 50:50 ialah 13.73% dan nisbah 25:75 ialah 14.68% manakala bagi penanaman jagung secara tunggal ialah 10.83%. Nisbah jagung:soya 50:50 berjaya memberikan hasil protein tertinggi (1886.45 kg/ha) berbanding kombinasi nisbah yang lain. Eksperimen ketiga dijalankan bagi menilai kesan 10 jenis rawatan baja terhadap hasil dan kualiti foraj jagung-soya. Hasil kajian mendapati baja kimia (NPK) memberikan hasil dan kualiti foraj lebih tinggi berbanding baja organik dan baja bio ($p<0.05$). Kombinasi baja kimia dan baja organik dengan nisbah 50:50 menghasilkan berat kering hasil yang menyamai berat kering hasil dari rawatan 100% NPK. Ini berkemungkinan disifatkan kepada perlepasan nutrien secara beransur-ansur seperti yang diperlukan oleh tanaman sepanjang masa tumbesaran daripada baja kimia dan baja tahi ayam. Kombinasi NPK dan (CM) juga menghasilkan tinggi pokok, kadar pertumbuhan tanaman (CGR) dan indeks luas daun (LAI) yang lebih tinggi berbanding rawatan menggunakan CM sahaja. Keputusan CGR dan LAI dari kombinasi NPK dengan CM juga tidak menunjukkan perbezaan bererti dengan rawatan 100% NPK. Kandungan protein kasar (CP) turut didapati tidak berbeza antara rawatan 100% NPK (14.48%) dan kombinasi NPK dan CM dengan nisbah 50:50 (14.55%). Namun, nilai ARA adalah lebih tinggi dalam rawatan tiada penggunaan baja, baja bio sahaja, dan kombinasi baja bio dengan NPK atau CM berbanding penggunaan baja kimia dan baja organik semata-mata. Secara keseluruhannya, kajian ini membuktikan bahawa penanaman selingan jagung dengan kekacang mampu menghasilkan kualiti dan kuantiti foraj yang tinggi, meningkatkan jumlah hasil protein, mengurangkan keperluan untuk makanan tambahan protein dan mengurangkan penggunaan baja kimia seperti yang sering diamalkan dalam penanaman jagung tunggal dengan nisbah jagung:soya 50:50 dan kombinasi baja kimia dan baja tahi ayam adalah yang terbaik daripada kombinasi yang lain berdasarkan peningkatan hasil silaj, hasil protein dan nilai CP.

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

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADF	Acid detergent fiber
ADL	Acid detergent lignin
ANOVA	Analysis of variance
ARA	Acetylene reduction assey
BF	Biofertilizer
CGR	Crop growth rate
CM	Chicken manure
CP	Crude protein
CV	Coefficient of variance
DM	Dry matter
DMY	Dry matter yield
DMD	Dry matter digestibility
FYM	Farm yard manure
GA	Ground area
GC	Gas chromatography
INM	Integrated nutrient management
LA	Leaf area
LAI	Leaf area index
LER	Land equivalent ratio
LSD	Least Significant Difference
MOP	Muriate of potash
NDF	Neutral detergent fiber
NIRS	Near infrared reflectance spectroscopy
PGPB	Plant growth promoting bacteria
PGPR	Plant growth promoting rhizobacteria
PM	Poultry manure
R^2	Coefficient of determination
RCBD	Randomized complete block design
RY	Relative yield
RYT	Relative yield total
TSP	Triple super phosphate
WSC	Water soluble carbohydrate

CHAPTER 1

INTRODUCTION

Forage from corn has high value for food, high yield capability, short-growth period, and is suitable as forage and feed for poultry and livestock and it is gaining an essential position in the cropping system (Saif et al., 2003). Feed products from corn are characterized by high-energy content, but relatively low content of crude protein with low biological value (Summers, 2001; Mlynár et al., 2004). The low protein concentration in forage corn can be augmented simply by incorporating protein-rich ingredients such as soybean (Choukan, 1997). Intercropping of corn and legume is considered best for subsistence food production system (Tsubo et al., 2005; Egbe and Adeyemo, 2006). Corn-legume intercrops could substantially increase forage quantity and quality and decrease requirements for protein supplements as compared with the corn monocultures (Liu et al., 2006; Javanmard et al., 2009).

Alternatively, intercropping system is very suitable for organic production because these cropping systems ensure more efficient use of land, greater yield stability, greater diversity of produce and better soil and water conservation (Oljaca et al., 2000; Dolijanovic et al., 2007). The intercropping system greatly contributes to crop production by its effective utilization of resources, as compared to the sole cropping system (Inal et al., 2007).

Successful intercropping of corn and soybean has been reported since soybean is often used to increase the typically low protein content of corn silage. Substantial information has been obtained on the corn-soybean model (Geren et al., 2008). However, there are significant gaps in the literature regarding the variability among different species of legume crops. Intercropping corn with pea, pigeonpea and soybean was good strategy to significantly increase corn productivity (Manna et al., 2003). This suggests that selecting intercrops that are best adapted to the growing environment would have the most positive effect on the companion crop by minimizing competition (Ahmad et al., 2014).

Different crop combination ratio for cereal-legume intercropping have been practiced by many researchers. Competition among mixtures is thought to be the major aspect affecting yield as compared to solitary cropping of cereals. Species or cultivar selections, seeding ratios, and competition capability within mixtures may affect the growth of the species used in intercropping systems. A number of indices such as LER, crop combination ratio, real yield loss, financial advantage, and intercropping benefits have been proposed to describe competition within and economic advantages of intercropping systems (Carr et al., 2004; Banik et al., 2006; Agegnehu et al., 2006; Dhima et al., 2007). Forage corn responds differently to crop combination ratio under

different environmental and cultural factors, which influence corn forage yield and quality (Carpici et al., 2010).

Corn productivity in tropical low external input systems is usually limited by low soil fertility because crop uptake leads to a gradual depletion of soil nutrient stocks. Since the use of chemical fertilizers is undesirable, the management of the fertilizer of these soils depends primarily on low cost processes based on nutrient recycling (Figueiredo et al., 2009). The main processes that may contribute to this are biological nitrogen fixation (BNF) and nutrient recycling through organic fertilization. Biological nitrogen fixation may contribute to corn growth and yield by direct fixation in corn, or through the use of legume plants either as crops in rotation or intercropped with corn. Either way, BNF can usually be considered as long-term sustainable nitrogen source for low external input corn production systems (Figueiredo et al., 2009).

Being a fast-growing plant with C_4 photosynthesis, corn requires plentiful supply of the essential elements nitrogen, phosphorus and potassium, which traditionally have been obtained by inputs of chemical fertilizers to replenish soil nitrogen and phosphorus, resulting in high costs and environmental pollution (Dai et al., 2004; Awodun et al., 2007). The harmful effects on the environment of heavy use of nitrogen fertilizer are becoming more evident. There is a need for sustainable farming, which maintains soil fertilizer by using renewable resources easily and cheaply available on the farm. The supply of other nutrients such as phosphorus can also be enhanced with the use of biofertilizers (Mayer et al., 2008; Oliveira et al., 2009). Organic fertilizers including farmyard manure, chicken manure, sheep manure, and biofertilizer may be used for crop production as a substitute of chemical fertilizers (Khan et al., 2005). Organic fertilizers improve soil fertility without leaving any residual effects in the soil and are much cheaper as compared to chemical fertilizers (Chater and Gasser, 1970).

Application of organic manure alone to sustain cropping has been reported to be inadequate due to their relatively low nutrient contents and their inability to provide a sufficient amount of nutrients. Integrated nutrient management approaches, where inorganic and organic fertilizers are combined, have been suggested as an efficient approach for crop production (Palm et al., 1997).

Therefore, this study was conducted with the following objectives:

1) To identify the best legume species to use for intercropping with corn.
2) To determine nutritive quality, physiological traits and performance of forage corn intercropped with legume under different crop combination ratios.
3) To determine the effect of chemical, organic and biofertilizers on improvement of quality and quantity in forage corn intercropped with legume.
4) To quantify biological nitrogen fixation (BNF) by legumes intercropped with corn.

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