PERFORMANCE OF MAIZE MUNGBEAN INTERCROPPING GROWN UNDER DIFFERENT PLANTING GEOMETRY

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Dedicated to

My

Beloved Parents

CERTIFICATE

This is to certify that the thesis entitled, "PERFORMANCE OF MAIZE MUNGBEAN INTERCROPPING UNDER DIFFERENT PLANTING GEOMETRY" submitted to the Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in AGRONOMY embodies the results of a piece of bonafide research work carried out by TOSNIA TOHURA, Registration No. 04/01424 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has been duly acknowledged by her.

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The Author

PERFORMANCE OF MAIZE MUNGBEAN INTERCROPPING GROWN UNDER DIFFERENT PLANTING GEOMETRY

Abstract

A field experiment was carried out at Sher-e-Bangla Agricultural University farm to study the effect of intercropping summer mungbean with maize on the fodder and grain yield productivity under different planting geometry. There are fourteen (14) treatments were used for the present study viz. (i) T_1 = MPR + 4 MuR using MPR spacing = 37.5 cm, distance between adjacent MPR = 112.5 cm, Inter-MuR spacing = 30 cm, (ii) T_2 = MPR + 4 MuR using MPR spacing = 30 cm, distance between adjacent MPR = 100 cm, Inter-MuR to MuR = 25 cm, (iii) T_3 = MPR + 3 MuR using MPR spacing = 30 cm, distance between adjacent MPR = 100 cm, Inter-MuR to MuR = 30 cm, (iv) T_4 = MPR + 3 MuR using MPR spacing = 25 cm, distance between adjacent MPR = 85 cm, Inter-MuR to MuR = 30 cm, (v) T_5 = MPR + 3 MuR using MPR spacing = 25 cm, distance between adjacent MPR = 75 cm, Inter-MuR to MuR = 20 cm, (vi) T_6 = MPR + 4 MuR using MPR spacing = 25 cm, distance between adjacent MPR = 85 cm, Inter-MuR to MuR = 17 cm, (vii) T_7 = MPR + 4 MuR using MPR spacing = 37.5 cm, distance between adjacent MPR = 112.5 cm, Inter-MuR to MuR = 25 cm, (viii) T_8 = MPR + 4 MuR using MPR spacing = 30 cm, distance between adjacent MPR = 100 cm, Inter-MuR to MuR = 20 cm, (ix) T_9 = MPR + 3 MuR using MPR spacing = 30 cm, distance between adjacent MPR = 100 cm, Inter-MuR to MuR = 25 cm (x) T_{10} = MPR + 3 MuR using MPR spacing = 25 cm, distance between adjacent MPR = 85 cm, Inter-MuR to MuR = 25 cm, (xi) T_{11} = MPR + 2 MuR using MPR spacing = 25 cm, distance between adjacent MPR = 85 cm, Inter-MuR to MuR = 25 cm, (xii) T_{12} = MPR + 3 MuR using MPR spacing = 25 cm, distance between adjacent MPR = 85 cm, Inter-MuR to MuR = 17 cm, (xiii) T_{13} = Sole Maize (Row to row spacing = 75 cm) and (xiv) T_{14} = Sole Mungbean (Row to row spacing = 30 cm) where MPR = Maize Paired Row and MuR = Mungbean Row. In the intercropping treatments, maize was grown in paired row using varying spacing of 25-37.5 cm leaving inter-paired-rows space of 85-112.5 cm for sowing mungbean (2-4 rows). Results showed that both the sole maize and mungbean gave the highest per plant values in most of the plant parameters studied. The treatments did not show appreciable difference in plant height, number of leaves/plant and leaf area/plant of maize due to the varying row arrangements. Maize fresh weight/ha and mungbean seed yield/ha decreased drastically by 33 - 56% and 50- 81%, respectively. Among the intercropping treatments '4 row-mungbean 25 cm apart accommodated at the space of 112.5 cm left between maize paired rows' showed higher per plant maize fodder yield. But significantly higher fodder yield and dry weight of maize per hectare was found in sole maize. The sole maize showed significantly the highest values of yield and yield attributes. Among the intercropping treatments with 25 cm - apart maize paired rows leaving 85 cm space between paired rows accommodated with 2-3 rows of 25 cm apart – mungbean (T_{10}) gave comparatively higher values of yield and yield parameters of maize. The sole mungbean showed significantly the highest values of fodder and grain yield and also those of yield attributes. The highest net return, maize equivalent yield, LER and BCR were Tk.69615, 7307.67 Kg/ha, 1.43 and 2.74 respectively with the same treatment. However, the intercropping treatments showed inconsistent results in respect of growth, fodder and yield attributes.

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LIST OF ABBRIVIATIONS

BARI	=	Bangladesh Agricultural Research Institute
CBR	=	Cost Benefit Ratio
cm	=	Centimeter
^{0}C	=	Degree Centigrade
DAS	=	Days after sowing
et al.	=	and others *(at elli)*
Kg	=	Kilogram
Kg/ha	=	Kilogram/hectare
g	=	gram (s)
LER	=	Land Equivalent Ratio
LSD	=	Least Significant Difference
MOP	=	Muriate of Potash
m	=	Meter
P^{H}	=	Hydrogen ion conc.
RCBD	=	Randomized Complete Block Design
TSP	=	Triple Super Phosphate
t/ha	=	ton/hectare
%	=	Percent

Chapter 1

Introduction

Chapter 1

INTRODUCTION

As an agricultural country, most of the people of Bangladesh live on agriculture. Bangladesh is also an over populated country but the area of land is limited with small farm holdings. Increasing agricultural production per unit area of land is becoming most important step to cope with the present population growth in Bangladesh. In recent years, multiple cropping has been gaining importance as a means of more crop production in limited land area particularly in the countries with small size farm holdings. This system of farming is already in practice in Bangladesh, India, China, Taiwan, Srilanka, Malaysia, Hongkong, Vietnum, Africa and Latin America (Beet, 1977).

The scope for horizontal expansion of cultivable land in Bangladesh is almost out of question. Crop production scientists and farmers are now focusing their attention to increase food production to feed the ever-increasing population. Intercropping is not only a means of augmentation of crop production and monetary return over space and time but also provides insurance against total crop failures and / or provides better avenues of employment for the rural folk (Bandyopadhyay, 1984).

There is a little scope for increasing cultivable area in the world. Therefore, farmers in developing countries have also shown keen interest in intercropping practices to increase crop production vertically to meet their requirements for food, fibre and fodder from the existing area (Bandyopadhyay, 1984).

Though the practice of multiple cropping is becoming popular, yet its advantages are not ensured in all circumstances. The profitability, of course, depends on edaphic and biotic conditions and management practices. In last two or three decades, vigorous investigations of multiple cropping had been done in tropical regions. In most cases the practice was found to be profitable. Various preconditions are necessary for the success of multiple cropping. Some favorable important conditions are proper soil textural property, nutrient status of the soil, climatic conditions of the locality, nature of crops and crop combinations (Dalrymple, 1971).

Three types of crop combinations are generally recognized. Some are competitive, some are supplementary and some are complementary to each other. Usually crops belonging to the same family or types are competitive for nutrients moisture, space and others. But crops of different families, such as cereal and legume are usually complementary in nature, that is, they are mutually benefited by natural symbiosis and fixation of nitrogen in soils. Application of phosphorus sometimes enhances the rate of fixation of nitrogen and utilization of other nutrients by crops (Patwary *et al*., 1985).
early kharif-l crops so it can be fitted in kharif-1 maize crop for substantial increase of pulse production.

The intensification of crop production can be done through intercropping systems where two or more crops are grown simultaneously in the same land at the same time (Zandstra, 1979). In the tropical and sub-tropical regions, cereal-legumes intercropping are the most popular practices because of many additional advantages (Okigbo and Greenland, 1979; Willey, 1979 a, Karim *et al*. 1990; Akkteruzzaman and Quayyum, 1991; Torofder *et al*. 1992). Intercropping becomes most productive and economical when both the crops differ with genetic make up, photosynthetic pathway, growth habit, growth duration and demand of different growth resources (Fukai and Trenbath, 1993). Intercrop productivity also depends on the light availability within the canopy of component crops (Ross, 1981; Isoda *et al*., 1992; Takahashi and Nakaseko, 1993). In an intercropping system, light distribution within the canopy is governed by plant type, leaf orientation, plant density and planting arrangement of component crops. Since solar radiation provides the energy for photosynthesis, the amount of light intercepted by the canopy determines the biomass and crop productivity. Therefore, crop selection should be done in such a way that maximum light might be intercepted by the intercropped canopy for higher biomass and economic productivity. Despite many advantages of cereal-legumes intercropping systems all crop combination are not equally profitable (Mandal and Mahapatra, 1990; Shah *et al*., 1991). Economical viability of intercropping system depends on many factors such as production potential of component crops, cost of production and market prices of the commodities

Maize (*Zea mays* L.) is a cereal crop gradually assuming increasing importance in Bangladesh due to its high yield potentiality and versatile use. The agro-climatic condition of Bangladesh is favorable for its cultivation round the year. As a food it can be consumed directly as a green cobs, roasted cobs or popped grain, flour, sattu and its stalk can be used as cattle feed. As a commercial crop, maize is used for manufacturing starch, corn flakes, alcohol etc. (Thakur, 1980). It has been found that this crop can very well be fitted in cropping pattern under partially irrigated high land conditions (BARI, 1982). However, it competes with broadcast aus and summer grain legumes in kharif season and other upland crops in rabi season. To popularize maize and avoid competition with other crops, intercropping is a good technique where farmers may produce maize with other crops (pulses, vegetables etc.) simultaneously.

Mungbean (*Vigna radiata* L. Wilczek) is one of the major pulse crops in Bangladesh. It is a crop of the tropics and sub-tropics and requires a warm temperature regime. Mungbean may be grown as an intercrop with other tall crops like maize, sorghum, cotton, jute, sugarcane, pigeonpea etc. Beside, mungbean grown as early kharif-l crops so it can be fitted in kharif-1 maize crop for substantial increase of pulse production.

Both maize and mungbean are grown for grain as well as fodder in kahrif season. When intercropped, either maize or mungbean can be used as fodder remaining the rest for grain production. The harvesting stage as fodder of maize and mungbean has been identified to be the knee high (Paradkar and Sharma, 1993) and flowering stages respectively. That is maize-mungbean intercropping can be practiced for achieving two major objectives : i) to harvest maize as the main crop for grain production and mungbean either for both fodder and grain production and ii) to harvest mungbean as main crop for grain production and maize as fodder.

Row arrangement has a direct effect on the performance of both main and intercrop. For grain production the row to row distance for sole maize and mungbean is recommended to be 75 and 30 cm .To grow mungbean as grain intercrop, a number of studies has been carried out both at home and abroad due to rapid growth in urbanization during the last decades, the demand of milk and milk product is also increasing day by day. Dairy farm are more connected in the urban area then rural area. Moreover due to the lack of fodder cattle rearing is also halted in the rural area. So this is also incorporat to incorporate fodder crop is the existing cropping systems

Instead of uniform row of maize, paired row planting of maize is an advantageous management which ultimately improves the gross return by accordingly different legume crops between the wider spaces of paired maize rows. Singh (1979) observed that sorghum gave maximum yield and monetary advantages when grown between paired rows of maize. He reported that component crops being grown in wider spaces of paired row system enable the plants to utilize efficiently the soil nutrients and solar radiation. Karim *et al.* (1990) reported the monetary advantage from groundnut cultivation between paired rows of maize.

Using the paired rows of maize, mungbean can be grown between two adjacent paired rows examining the effects of different row and spacing arrangements of mungbean both on fodder and grain yields.

The present study was undertaken with the following objectives:

i. To study the planting geometry or row arrangement on the fodder yield of maize intercropped with mungbean.
ii. To study the planting geometry or row arrangement on the grain yield of maize intercropped with mungbean.
iii. To study the planting geometry or row arrangement on the fodder yield of mungbean intercropped with maize.
iv. To study the planting geometry or row arrangement on the grain yield of mungbean intercropped with maize.

Chapter 2
Review of literature

Chapter 2

REVIEW OF LITERATURE

An effort has been prepared in this chapter to present a brief review of research on intercropping of pulse crops with maize to obtain better fodder and grain yield. Crop production scientists and farmers are now focusing their attention to increase food production to feed the ever-increasing population. It is an established fact that intercropping system increases water utilization efficiency, shows higher land equivalent ratio and above all gives higher yield (Mengping and Zhangjinsong, 2004). Therefore, the available findings of the effect of row arrangement on the yield of maize as sole or intercropped have been briefly reviewed below:

Abubeker *et al.* (2006) conducted a study on the effects of maize-annual forage legume associations on maize and fodder production for 4 years in the sub-humid zone of western Ethiopia. *Lablab purpureus* (lablab) and *Vicia atropurpuria* (vicia) were grown as pure crops or as intercrops in maize at 2 planting dates (simultaneous vs delayed 6 weeks) for 3 consecutive years (1994-1996) and pure maize was planted in all plots in the fourth year (1997). Intercropping significantly ($P<0.05$) reduced grain yield in the 3rd year, but its effect on stover yield was not significant ($P>0.05$). Among the intercrops, simultaneous planting of lablab significantly ($P<0.05$) reduced grain and stover yield but increased forage dry matter (DM) yield. Lablab resulted in lower ($P<0.05$) grain yield and higher total fodder (maize stover+forage DM) yield than vicia intercropped simultaneously with maize. Delayed planting, however, did not affect ($P>0.05$) grain, stover, forage DM or total fodder yields. Forage yield of lablab was significantly ($P<0.05$) higher than that of *Vicia*, as both a monoculture and an intercrop planted simultaneously with maize. Plots under lablab and *Vicia* monocultures for the previous 3 years produced maize yields comparable with those on fertilised plots. Among intercrops, the residual effects of simultaneously planted lablab were ($P<0.05$) greater than for delayed planting. Grain yields following lablab were greater ($P<0.05$) than following *Vicia* both as a monoculture and as a simultaneously planted intercrop. When planted as a monoculture or simultaneously planted intercrop with maize, lablab appeared superior to *Vicia* in terms of its ability to improve both feed supply and soil fertility.

Muhammad *et al.* (2005) conducted a field trial during kharif 2000 at Barani Agricultural Research Station, Kohat, Pakistan, to determine the most profitable combination of cereal fodders with leguminous ones under the given fertility level of the soil. The treatment combinations were: (T_1) sole sorghum; (T_2); sole millet; (T_3) sole cowpea; (T_4) sole mungbean; (T_5) sorghum + cowpea; (T_6) millet+cowpea; (T_7) sorghum+mungbean; and (T_8) millet+mungbean. Results revealed that sorghum and millet being cereal fodder responded explicitly with legumes fodder, cowpeas and mungbean. Yield ranged from 3538-15 694 kg/ha. The maximum fodder yield was recorded from millet+cowpea, and the lowest yield was observed on sole mung treatment.

Sunitha and Raja (2005) conducted a field experiment during the 2002/03 kharif and rabi seasons in Andhra Pradesh, India, to study the effect of planting pattern and fertilizers on the yield of rice, and the residual effects of the treatments on sequential fodder maize. The treatments comprised: 3 planting patterns, namely normal planting (15×15 cm), planting with alleys (0.3-3.0-0.3 m) by adjusting plant population of alleys in the net plots, and planting *Sesbania rostrata* in alleys and in situ incorporation; and 3 fertilizer levels, namely 100% recommended dose of NPK fertilizer (RDF), 75% RDF and 75% RDF + 5 t farmyard manure/ha. The highest number of panicles, panicle length filled grains per panicle, 1000-grain weight and grain yield of rice, and maize fodder yield were obtained with *S. rostrata* planting in alleys and in situ corporation, and 75% RDF + 5 t farmyard manure/ha.

Bhatti *et. al.* (2005) conducted a field experiment on a sandy-clay loam soil in Faisalabad, Pakistan for two consecutive years (2001 and 2002) to evaluate the effect of intercrops and planting patterns on the agronomic traits of sesame. The planting patterns comprised 40 cm spaced single rows, 60 cm spaced 2-row strips and 100 cm spaced 4-row strips, while the cropping systems were sesame+mungbean, sesame+mashbean [*Vigna aconitifolia*], sesame+soyabean, sesame+cowpea and sesame alone. The various yield components of sesame such as number of capsules plant^{-1}, seed weight plant^{-1}, 1000-seed weight and plant height were affected significantly by different intercropping systems and planting patterns. Grain legumes intercropping reduced the seed yield of sesame to a significant level by adversely affecting its yield components. However, the additional harvest of each intercrop more than compensated for the loss in sesame production. Among the intercropping patterns, sesame intercropped with mungbean, mashbean, soyabean and cowpea in the pattern of 100 cm spaced 4-row strips proved to be feasible, easily workable and more productive than sesame monocropping. Among the intercropping systems, sesame+mungbean or sesame+mashbean were found to be superior to all other intercropping systems under study.

Gbaraneh and Ikpe (2004) conducted a field experiment in Onne, Nigeria, during the 1998 and 1999 cropping seasons, to study the influence of lablab on maize grain and fodder (stover) yield. Lablab was simultaneously sown in maize on the same day and also undersown in maize at 2, 4, 6 and 8 weeks after maize planting (WAP) while sole maize and sole lablab were used as control. Simultaneous planting reduced maize grain yield by 40-63% relative to the sole maize crop while higher grain yield was obtained when undersowing of lablab was delayed beyond 2 weeks after planting. Unlike maize grain yield, highest lablab dry matter fodder yield was obtained when maize and lablab were simultaneously sown, and declined progressively with delayed undersowing of lablab while maize fodder yield was not affected by time of lablab undersowing. Time of lablab undersowing positively influenced total fodder (maize + lablab) yield. When fed to livestock, rate of digestibility was higher in lablab fodder than the maize fodder, indicating that lablab fodder enhanced the digestibility of lablab-maize forage. Undersowing of lablab in maize not latter than 4 WAP, effectively controlled weed infestation in the intercrops than undersowing later.

Lakshmi *et al.* (2003) conducted a study at the Cropping System Research Centre, Karaman, Kerala, India, during the summer season 1999-2001, to evaluate the fodder production potential of short duration cereal fodder and cereal legume mixtures in rice fallows. The treatments consisted of three cereal fodders and their combinations with fodder cowpea: (1) fodder maize (*Zea mays*); (2) fodder sorghum (Sorghum); (3) fodder bajra (*Pennisetum glaucum*); (4) fodder maize + fodder cowpea (*Vigna unguiculata*); (5) fodder sorghum + fodder cowpea; (6) fodder bajra + fodder cowpea. The growth attributes showed significantly higher plant height of cereal in the fodder sorghum, whereas the leaf : stem ratio of fodder maize was maximum. Maize as sole crop gave significantly higher green and dry fodder yield followed by maize+cowpea intercropping in all the years and in the pooled analysis result. The fodder yield of maize in combination with cowpea was lower than that of sole maize.

Saini and Kapur (2000) carried out a field experiment for three consecutive years (1996-99) at the Sugarcane Research Station, Jalandhar, Indian Punjab, to investigate the feasibility and profitability of intercropping one or two rows of okra, sathi maize or maize fodder in spring sugarcane. Results reveal that, with the exception of intercropping one row of okra or sathi maize, the treatments depressed cane yield significantly. Intercropping one row of okra in spring sugarcane gave the highest cane yield equivalent (80.6 t/ha) and net profit of Rs 20 368/ha. The corresponding figures for one and two rows of sathi maize were 57.5 t/ha and 53.3 t/ha, and Rs 15 571/ha and Rs 9321/ha, respectively.

Intercropping of maize fodder depressed cane yield by 51.6%, resulting in a net loss of Rs 1197/ha as compared to pure cane.

Channakeshava and Ramaprasanna (2000) conducted a study during kharif 1995 and 1996 in bangalore, Karnataka, India to investigate the effect of plant spacings and fertilizer levels on seed yield and yield components of the African tall fodder maize. Six spacing and three fertilizer levels were tried in randomized block design with three replications. Planting African tall maize at 75 × 45 cm spacing recorded significantly higher seed yield (53.27 q/ha) compared with all other spacings. While closer spacing of 45 × 30 cm registered the lowest seed yield (25.35 q/ha). Similarly, the application of 200:100:75 kg NPK per ha caused significantly higher seed yield of 42.5 q per ha compared with the application of either 100:50:25 or 150:75:50 kg NPK per ha. Spacings and fertilizer level interaction resulted in significant differences in the seed yield in African tall fodder maize. Sowing at 75 × 45 cm wider spacing with 200:100:75 kg NPK per ha resulted in higher seed yield (54.02 q/ha) compared with the other treatment combinations, while closer spacing of 45 × 30 cm with 100:50:25 kg NPK per ha registered significantly less seed yield (23.57 q/ha) compared with the other treatments..

Azim *et al.* (2000) conducted a study to examine the influence of maize (*Zea mays*) and cowpea (*Vigna unguiculata*) intercropping on fodder biomass production and silage characteristics. Maize fodder was cultivated alone and intercropped with cowpea at seed ratio of 85:15 and 70:30. Fodder was harvested at heading stage (35% DM). The data indicated a significant increase in biomass and CP production of maize intercropped with cowpea at a seed ratio of 70:30 followed by a seed ratio of 85:15 compared with maize alone. However, no difference was observed in the production of total digestible nutrients among the treatments. Four types of silages from maize alone, maize and cowpea (85:15), maize and cowpea (70:30) and maize supplemented with

2.5% urea were prepared. After 60 days of ensiling period, silage samples were analysed for proximate composition and fermentation characteristics. CP and lactic acid values of silages I, II, III and IV were 8.52, 9.82, 14.90 and 13.96% and 9.00, 9.38, 10.86 and 7.43%, respectively. In situ DM digestibility was maximum in silage III followed by silages II, IV and I. The results suggest that intercropping of maize and cowpea at a seed ratio of 70:30 increases fodder production and results in quality silage.

Satyanarayana and Veeranna (1998) trialed on red lateritic soil in 1993-95, sugarcane was planted in single or paired rows and intercropped with cowpeas, soyabeans, field beans [*Phaseolus vulgaris*] or maize grown for fodder. The effect of planting method on cane yield was not significant, although yield was 10.1% higher in paired rows. Among intercrops, fodder maize had the greatest adverse effect (25.9%) on cane yield, followed by fodder cowpeas (15.9%) and fodder soyabeans (9.6%). Sugarcane grown alone had the highest net and gross returns. Yields of sugarcane and intercrops are tabulated for both years and all treatments.

Krishna *et al.* (1998) conducted a field experiment during 1991 and 1992 on clay loam soil at Rudrur, Andhra Pradesh, compared sole crops of forage maize cv. African Tall (30 or 45 cm row spacing) with maize intercropped or mixed cropped with cowpeas cv. EC 4216. Fertilizer rates of 0, 60, 120 or 180 kg N/ha were applied. Green and dry fodder yields were highest when a maize + cowpea mixed crop was sown at 30 cm row spacing. Percentage crude protein was higher in the intercropping treatments than in pure maize. Fodder yield and percentage crude protein increased linearly with increasing N rate, while crude fibre content decreased with increasing N.

Shehu and Alhassan (1997) made a comparison over 2 years in the savanna zone of Nigeria between maize intercropped at different interrow maize spacings with a legume, *Stylosanthes hamata*, and pure stands of maize and *S.*

hamata. Intercropping reduced the yield of maize grain, especially when the distance between maize rows was increased beyond 50 cm. Fodder (maize stover + *S. hamata*) dry matter and crude protein yields were only slightly greater at wide interrow spacing of the maize. The reduction in maize grain dry matter yield with intercropping was greater than the increase in fodder dry matter yield obtained.

Mahajan (1995) conducted a field experiment in 1990-93 in Himachal Pradesh where barley was grown on plots green manured with cowpeas, *Sesbania cannabina*, *Crotalaria juncea* or *Cyamopsis tetragonoloba* or plots previously left fallow and was given 20, 40 or 60 kg N/ha. In 1992/93, maize (*Zea mays*)-cowpeas (*Vigna unguiculata*) fodder crop was grown on the manured plots before barley and was given 40, 80 or 120 kg N/ha. Barley grain yield was highest with *S. cannabina* in 1990/91 (2.09 t/ha) and *C. juncea* in 1991/92 (3.79 t). In 1992/93 grain yield was not significantly affected by green manures. Grain yield was highest with 60 kg N. Maize-cowpea fodder yield was highest with cowpea green manure (31.52 t/ha) and increased with up to 80 kg N.

Sharanappa and Shivaraj (1995) conducted a field experiment during 1989-90 and 1990-91 at Bangalore, rainy-season. Rice (*Oryza sativa*) was planted after green manure crops *Sesbania rostrata*, sunnhemp (*Crotalaria juncea*) or soyabeans (*Glycine max*) grown as sole crops or as intercrops (1:1) with fodder maize (*Zea mays*), after fodder maize grown alone, or after a fallow. The green manures were incorporated into the soil before rice planting. The *S. rostrata* and sunnhemp green manures improved the soil N, P and K contents under a subsequent rice-sunflower sequence. The biomass yield and the total productivity of rice and sunflowers were highest with *S. rostrata* green manure, followed by sunnhemp green manure. Incorporation of the green manure crops intercropped with maize or sole soyabeans did not improve the yield significantly. The soil organic carbon and available N, P and K contents were improved on inclusion of sunn hemp or *S. rostrata* in the sequence. Biomass yield and economic yield of rice and sunflower were highest with application of 100 kg N/ha.

Ali (1993) conducted a field experiments at Kanaipur, Faridpur and observed that the highest grain and fodder yields, land equivalent ratio and net returns were achieved from intercropping maize with *Vigna radiata*.

Sunitha and Sreekantan (1994) conducted a field experiment in 1988/89 at Vellayani, Kerala where cowpeas cv. C-152 and maize cv. CO-H-2 were grown alone or intercropped. Under intercropping, cowpeas were grown in alternate, paired or triple rows. Both crops received the recommended NPK fertilizer rate, 75 or 50% of this rate. Cowpea seed yield was not significantly affected by intercropping, but maize fodder yields decreased under paired or triple cropping of cowpeas. Maize fodder yields were decreased by decreasing the NPK rate, but cowpea seed yields were unaffected by the NPK rates. Maize fodder yield was highest under intercropping (row ratio 1:1) where both crops received the recommended NPK rate.

Thiyagarajan (1994) conducted a field experiment in 1987-89 at Coimbatore, Tamil Nadu, where maize cv. Co.1 was intercropped with cowpeas cv. Co.4, soyabeans cv. Co.1 or maize cv. Co.1 grown for fodder. Maize seed quality was generally not affected by intercropping with the legumes. Soyabeans and cowpeas seed quality were lower from intercropping than sole cropping in terms of seed recovery, germination, 100-seed weight producing less vigorous seedlings. Soyabean seed quality was significantly decreased when intercropped with fodder maize.

Paradkar and Sharma (1993) conducted a field experiment on Vertisol in 1988-89 at Chhindwara, Madhya Pradesh where grain maize cv. Chandan Makka 3 and fodder maize cv. Africa Tall were sown in alternate rows or grown alone. Fodder maize was cut at knee-high stage, tasseling and milk stage. Grain yields were decreased in 1988 and 1989 by 19 and 17%, 48 and 42% and 69 and 66% when the fodder maize was cut at the 3 stages, respectively. Fresh fodder yields were decreased by just under 50% with intercropping. The highest monetary return was obtained from the intercrop where the fodder maize was cut at tasseling.

Ramachandra *et al.* (1993) conducted a field experiment on sandy loam during the kharif [monsoon] season of 1991/92 at Bangalore, Karnataka. Maize cv. South African Tall was intercropped with cowpeas cv. C-152, Dolichos lablab or *Vigna umbellata*. The legumes were grown for either grain or fodder. Maize/cowpeas (grain) intercrop gave the highest net return followed by sole maize. Maize/*V. umbellata* (fodder) intercrop had the highest CP content of 12.04%. Maize yield was highest in sole crops followed by maize/cowpeas (grain) intercrop.

Intercropping is an age old practice and it has been recognized as a very common practice throughout the developing tropics (Willey, 1979). It makes better use of sunlight, land and water. It may have some beneficial effects on pest and disease problems. In almost all cases, it gives higher total production; monetary returns and greater resources use efficiently and increase the land productivity by almost 60 percent (IRRI, 1973).

Krantz *et al*. (1976) observed that mixed/intercropping legume and non-legume covered risk, earned more profit and stabilized production, improved soil fertility, conserved moisture and facilitated efficient labor distribution.

A field trial in winter seasons was carried out with wheat and lentils grown alone or intercropped in a 4:2 row ratio. The wheat in pure stand was given 80 kg N + 16 kg P + 16 kg K/ha (100% NPK), while sole lentil received 20 kg N + 16 kg P/ha (100% NP). Intercrops were given 8 different combinations of fertilizers. Wheat grain yield was 3.29 t/ha in pure stand and 2.73 - 3.12 t/ha when intercropped. Lentil seed yield was 1.53 t/ha in pure stand and 0.22 - 0.41 t/ha when intercropped. The highest wheat-equivalent yield and net returns were obtained when wheat with 100% NPK was intercropped with lentils fertilized with 75% NP (Verma *et al*., 2008).

Ahmed *et al*. (2000 a) conducted a field experiment on maize-mungbean intercropping to assess the yield advantage from the viewpoint of growth process in Japan, during June-October 1999. Three maize densities (75 x 50, 75 x 30, 75 x 15 cm^2) intercropped with one row of mungbean did not affect the maize yield, but the yields of mungbean were greatly affected. The maximum and minimum yields of mungbean were obtained in sole mungbean and mungbean intercropped with a high-density maize plot, respectively. Land equivalent ratios (LER) were higher than 1.0 in all intercropping plots where highest LER (1.79) was observed in the low-density of maize plot.

Ahmed *et al*. (2000 b) also conducted an experiment on maize-mung bean intercropping to find out suitable mungbean cultivars (Kanti and BARI-mung-5) and its sowing systems in intercropping and to analyze the yield improvement from the viewpoint of growth process with the consideration of canopy structure and light interception. Maize yield did not differ significantly due to intercropping.

In sole crop situation of mungbean, the variety BARI-mung-5 showed higher yield than Kanti but in intercropping situation, BARI-mung-5 yield was reduced more than Kanti. The yield reduction of BARI-mung-5 was 73% and that of Kanti was 35-44%. There was no significant difference between the yield of 1 row and 2 rows sowing systems of mung bean in intercrop treatments for both of the mungbean cultivars. Land equivalent ratio (LER) of plots of maize intercropped with both cultivars was evident. The highest LER (1.58) was observed in intercropped with mungbean variety Kanti.

Many scientists have reported that legume may benefit the associated non-legume crops (Waghmare *et al.*, 2005). Inclusion of legumes in the intercropping system was likely to be beneficial as they could fix atmospheric nitrogen into the soil and help in the utilization of soil moisture from deeper soil layers (Bautista, 2006).

Polthanee *et al.* (1999) conducted an experiment on mungbeans cv. Chainat 36 where mungbean sown 50, 65 or 80 days after emergence of maize cv. Suwan 5 in a relay cropping system. Grain yield and yield components of maize were not significantly affected by relay sowing dates, with yield range 2113-2131 kg/ha. Mungbean yield was 630 kg/ha in pure stand, but in relay cropping systems yield was only 232 and 68 kg/ha when it was sown 50 and 80 DAE. Land equivalent ratio of relay cropping ranged from 1.11 to 1.36 when mungbean sown 80 and 50 days after maize emergence. In economic evaluation, the relay cropping treatments gave 7 to 24% monetary advantage over the sole maize cropping.

Patra *et al.* (1999) observed the increased number of cobs per plant due to temporal complementary in maize-legume association. He also reported that the yield of all the intercrops with maize decreased compared with their sole crops. More shading effect from maize particularly at 1:1 row ratio and its early vigour might be reduced the yield of intercrops. Singh *et al.* (1988) reported that combined yield of maize + legume was higher both at 1:1 and 1:2 rows than monoculture of maize. It was possibly due to increased yield of maize in addition to bonus yield of legumes. Patra *et al.* (1990) also reported that association of soybean gave the highest combined yield at both the row ratios, whereas the association between maize and sesame recorded the lowest combined yield due to severe competition.

Farmers in developing countries have shown keen interest in intercropping practice because of its potentiality for increasing crop production to meet their requirements for food, fibre and fodder from existing area (Bandyopadhyay, 1984).

Quayyum *et al.* (1999) conducted an experiment on crop weed competition in maize sole and maize + blackgram intercropping system. The highest maize equivalent yield, gross return, net return and benefit cost ratio were recorded from one hand weeding 42 DAS (days after sowing) and earthing up 21 DAS. But in maize sole situation, two hand weedings 21 and 42 DAS with earthing up DAS showed higher benefit cost ratio than the other treatments.

Nag *et al.* (1996) reported that monoculture of maize, cowpea, khesari, mungbean, groundnut and maize intercropped with legumes (cowpea, khesari, mungbean and groundnut) in paired rows were compared in an experiment conducted during 1993-94. Highest maize equivalent yield (6973 kg/ha) was obtained from maize + mungbean Intercropping, but maize + groundnut combination gave the highest maize equivalent yield (5615 kg/ha) in 1994-95. Maize + mungbean and maize + groundnut also gave the highest net return (Tk. 50952/ha and Tk. 40245/ha.) during 1993-94 and 94-95, respectively. But on an average maize + cowpea and maize + khesari combination gave the highest benefit cost ratio (5.34 and 5.32) and land equivalent ratio (1.35).

The intercropping experiment on wheat, gram, lentil and mustard showed that the combinations of wheat with mustard and with gram were quite compatible producing 19 and 11 percent, respectively more yield than those under monocrops (Razzaque, 1980).

Senaratne *et al*. (1995) conducted an experiment on 15N-labelled soil, maize intercropped with cowpea (*Vigna unguiculata*), mungbean (*Vigna radiata*) and groundnuts (*Arachis hypogea*). Intercropped groundnuts fixed the highest amount of N from the atmosphere (552 mg plant^{-1}), deriving 85% of its N from the atmosphere. Intercropped cowpea and mungbean fixed 161 and 197 mg N plant^{-1}, obtaining 81% and 78% of their N content from the atmosphere, respectively. The proportion of N derived by maize from the associated legume varied from 7 to 11% for *V. radiata*, 11 to 20% for *V. unguiculata* and 12 to 26% for groundnuts, which amounted to about 19-22, 20-45 and 33-60 mg N maize plant^{-1}, respectively. The high N fixation potential of intercropped groundnuts and their relatively low harvest index for N appeared to contribute to the greater beneficial effect on the associated crop.

Kumari *et al.* (2003) conducted a field experiment on the sandy loam soil to evaluate weed management practices in a wheat based intercropping system. The highest land equivalent ratio was obtained in the wheat + chickpea intercropping. Weeding thrice showed higher land equivalent ratio compared to the other weed management systems.

Hirota *et al*. (1995) conducted a field experiment on maize and mungbean cv. Kanti as pure stands and intercropped at different plant densities. Two rows of mungbean (266 x 10^3 plants/ha) were sown together with one row of maize (26000 to 90000 plants/ha) in the intercrops, while pure stand densities were 53000 plants/ha for maize and 333000 plants/ha for mungbean. The grain yield of maize in monoculture was about 484 g/m^2 and 158-219 g/ m^2 when intercropped. Seed yield of mungbean was 72 g/m^2 in pure stand, 68 g/m^2 at the lowest density of maize when intercropped, and 20-21 g/m^2 in the other intercropping treatments. Land equivalent ratio (LER) was highest (1.39) at the lowest maize density where as other plots was <1.0.

Quayyum and Maniruzzaman (1995) carried out an experiment to evaluate the intercropping of maize (*Zea mays* L.) and rice (*oryza sativa* L.) with blackgram (*Phaseolus mungo* L.). Aus rice (BR 21), maize (Barnali) and blackgram (Barimash) as sole crops and blackgram as intercrop or strip crop with rice and maize. Aus rice yield varied from 1.43 to 2.23 t/ha, depending on the treatments. Reduction in yield of rice under inter or strip cropping with blackgram was almost proportional to the land area. Blackgram yield ranged from 0.33 to 0.79 t/ha and that of maize from 2.48 to 3.39 t/ha. The highest rice-equivalent yield (3.35 t/ha) and gross return (Rs 14,103/ha) were obtained from maize-paired row (100%) + blackgram rows (44%).

Torofder *et al*. (1992) conducted an experiment to determine the effect of intercropping maize with different legumes (mungbean, soybean, cowpea, blackgram and groundnut). Maize yield of 2.60 t/ha from maize + groundnut combination was second only to that from maize monoculture (2.90 t/ha). An additional 0.81 t/ha groundnut was obtained from the intercropping which also gave the highest maize equivalent yield (4.22 t/ha), land equivalent ratio (LER) (1.56), gross margin (Tk. 10900 /ha and benefit cost ratio (2.06)

Nargis *et al*. (2004) evaluated an experiment on mixed cropping of lentil (100%) and wheat (20, 40, 60 or 80%). It was observed that in lentil, 100% lentil + 40% wheat gave the highest number of branches per plant (3.25), whereas 100% lentil + 60% wheat recorded the greatest plant height (35.70 cm). The highest number of seeds per plant (47) and seed yield (1278 kg/ha) of lentil were obtained under line sowing. Sole wheat (broadcast) produced the tallest plants (89.15 cm) and the longest spikes (9.84 cm). The highest land equivalent ratio (1.52), monetary advantage (63%) and benefit : cost ratio (1.84) were recorded for intercropping lentil (100%) and wheat (40%).

Karim *et al*. (1990) conducted an experiment to study the effect of planting system maize with rows of groundnut grown as mono and / intercrop.

Maximum grain yield of maize (2.96 t/ha) was obtained from monoculture in uniform row which was identical to maize uniform row, with two or three row groundnut. Higher maize and groundnut equivalent was found in uniform 3 or paired 6 rows of groundnut. Both the former and the latter combination gave higher LER (1.44) and net return of Tk. 8719 and 8502 /ha, having same benefit cost ratio.

The magnitude yield of advantage of intercropping system could be determined by the use of LER value (Ofori and Stern, 1987). The concept of land equivalent ratio or relative yield total assumed an important way in evaluating the benefit of intercropping of two dissimilar crops grown in the same field (Fisher, 1977). If LER is more than 1.00 then intercropping gives agronomic advantages over monoculture practice. The higher is the LER, the more is the agronomic benefit of intercropping systems (Palaniappan, 1988).

Mixed or intercropping has been reported to have many advantages for the farmers. It increased the total production; acted as insurance against failure of the principal crop and better utilization of inter space in crops. It also reduced the cost of intercultural operation and increased the fertility of the soil (Oleksy and Szmigiel, 2007).

Akanda and Quayyum (1982) got an LER value of 1.72 in a maize and groundnut combination. The land equivalent ratio is the most frequently used index to determine the effectiveness of intercropping relative to growing crops separately (Willey, 1985). Intercropping corn with legume mixture (mungbean, soybean and groundnut) increased LER by 30 to 60% over monoculture crops (IRRI, 1974). When intercropped maize with legumes, the highest LER (1.74) was obtained from maize + fieldpea combination (Uddin and Sattar, 1993). Maize + frenchbean in row ratio of 1:2 recorded the highest LER (1.61) and lowest LER (1.07) was found in maize-greengram system in 3:1 ratio (Pandita *et al.*, 1998). The above values indicated that intercropping system is more efficient in utilizing resources and resulted higher productivity than the sole cropping.

Land equivalent ratio (LER) is a good measure for evaluating land productivity, in physical terms of a sole crop vs intercrop (Chowdhury, 1979). When two or more dissimilar crops are grown in the same filed at the same time, LER measures the crop productivity of a unit land area sown to a crop mixture *vis*-a-*vis* the crop productivity of sole components of the mixture grown on an equivalent land area (Mead and Willey, 1980; Shaner *et al*. 1982).

An index of combined yield, LER provides a quantitative evaluation of the yield advantage due to intercropping (Willey, 1979 b). LER could be used either as an index of biological efficiency to evaluate the effects of various agronomic variables (fertility levels, density level and spacing, comparison of cultivar performance, relative time of sowing and crop combinations) on an intercropping system in a locality or as an index of productivity across geographical location to compare a variety of intercropping systems (Chetty and Readdy, 1984).

A field experiment was conducted at West Bengal to study the performance of wheat and lentil. The crops were grown in pure stands or intercropped under different levels of irrigation. Results revealed that mean wheat grain yield was 2.08 t/ha without irrigation, 2.99 t/ha with two irrigations (21 and 65 days after sowing) and 3.40 t/ha with irrigations at 4 critical growth stages. Lentil yield was 0.68 t/ha without irrigation, 1.16 t/ha with two irrigations at branching and flowering, and 0.94 t with 4 irrigations (Ghosh *et al*., 1997).

Harwood (1979) defined LER as the "area needed under sole cropping to give as much produce as one hectare of intercropping or mixed cropping at the same management level, expressed as a ratio". The LER is the sum of the fractions of the yield of the intercrops relative to their sole crop yields (Andrwes and Kassam, 1976). At IRRI (1974) it was found that a corn + legume mixture increased LER from 1.3 to 1.6 over a monoculture corn. In this experiment it was found that corn + mungbean mixture increased land productivity by 50 percent whereas green soybean and groundnut with corn increased land productivity by 60 percent.

Ali (1993) conducted a field experiments to determine the optimum fertilizer rate and row ratio of wheat and chickpeas in the late-sown irrigated condition. Of the 3 populations tested (2 : 2, 2 : 1 and 3 : 1 row ratios of wheat: chickpeas), the 2 : 2 row ratios allowed more light interception and transmission to the lower canopy and gave significantly higher yield (4.16 t/ha wheat equivalent) and land equivalent ratio (LER) than the other treatments. Fertilizers rates used were those of the recommended ones (120 kg N + 26.4 kg P + 50 kg K/ha) in both cases.

Quayyum *et al*. (1987) conducted an experiment on intercropping maize at row distances of 75, 100 and 125 cm with one, two and three rows of chickpea between maize rows. Two years data revealed intercropping of maize grown at a spacing of 75 x 25 cm with two rows of chickpea producing the highest total maize equivalent yield of 5590 kg/ha. This was 22% higher than the yield of sole crop of maize. Two combined, maize + chicpea, yield gave the highest net return of Taka 12803.00 /ha and highest LER of 1.35 indicating that the mixture was 35% more efficient in terms of land utilization than a sole crop of maize.

Cereal-legume intercropping has been advocated by many authors (Akanda and Quayyum, 1982; Hashem and Maniruzzaman, 1986; Akhtaruzzaman and Quayyum, 1991, Akthtaruzzaman *et al*., 1993). In cereal-legume intercropping system, yield reduction of legumes has been reported in almost all cases. It is likely that legume plants suffer from shade underneath tall maize plants and could not achieve its yield potential whereas maize yields were usually less affected than legume yields. It has been observed that the yield of both the crops reduce when intercropped, but combined yield could be higher. It was observed that the yield of legume is usually more depressed in mixed cropping than that of non-legume (Akinola *et al*., 1971).

Legumes grown as companion crops were found to be beneficial for the principal crop through nitrogen fixation. Moreover, legumes may help in the utilization of soil moisture from deeper soil layers. In intercropping of maize with cowpeas in both dry and rainy season. Cowpea gave the best result with respect to soil improvement and weed control (Bautista, 1988).

Intercropping is practiced traditionally in many parts of Asia, Africa, Latin America, some temperate regions of Australia and the United States (Searle *et al*., 1981; Allen and Obura, 1983; Chui and Shibles, 1984). Inter or mixed cropping is also widely practiced by the farmers of Bangladesh. There are many established and speculated advantages for intercropping systems such as higher grain yields, greater land use efficiency and improvement of soil fertility by the component legume crops (Willey 1979 b, Andrew and Kassam, 1976).

Hashem and Maniruzzaman (1986) reported that almost all cases intercropping gave higher monetary return than the sole crop. Rahman *et al.* (1982) found higher monetary return in a maize + mungbean combination. Akanda and Quayyum (1982) found maize + groundnut combination producing maximum cost benefit ratio of 1:3.05 in 100% maize + 50% groundnut combination at 60 kg/ha N level.

Different nutritional demands of the two dissimilar crops grown together may create competition problems in meeting the nutrient needs of the crops grown simultaneously. However, in such intercropping mixture where legume and cereal are grown in association the rate of nitrogen fertilizer to be used is a mute question. In an experiment of cotton + legume (mungbean and groundnut) intercrops, Giri and Upadhyay (1980) showed that yield of seed cotton and monetary return per hectare were increased significantly with every higher level of nitrogen. Kalra and Gangwar (1980) reported that total productivity increased by 29 to 37.5 percent with the application of nitrogen @ 80-120 kg/ha as compared with 40 kg/ha in an intercropping systems of maize and legumes. They also reported that the application of 80 kg N/ha was economically viable.

In an experiment, Gangwar and Kalra (1984) found that maize intercropped with mungbean and fertilized with 120 kg N/ha gave more yield than the application of 80 kg N/ha.

Xiao *et al*. (2003) conducted an experiment on intercropping of faba bean (*Vicia faba*) and wheat (*Triticum aestivum*) using different nitrogen sources. They found that without any root barrier, the growth of wheat plants were improved resulting in greater biomass production and N uptake. Biomass production and N uptake of faba bean were lowest in the treatment without a root barrier. This suggested that wheat had greater competitiveness than faba bean and that this competition leaded to a higher percentage of N fixations from atmospheric nitrogen.

Yadav (1981) obtained highest yield of maize at 120 kg N/ha in maize + pigeonpea intercrop. Pigeonpea as an intercrop did not increase the yield of maize at any level of nitrogen. It was concluded by Rajasejaran *et al.* (1983) that maximum economic return was obtained by growing maize with blackgram or onion with 100 kg N/ha. But application of 135 kg N/ha significantly increased grain yield compared with 65 or 100 N/ha. The highest total yield and net return was obtained from maize and groundnut intercropping at the plant population levels of 4.4×10^4 maize and 16.6×10^4 groundnut plants per hectare with 120 kg N/ha than 30 kg N/ha (Quayyum *et al.* 1985).

The main advantage for the use of legumes in intercropping and mixed cropping is as the saving of N-fertilizer (Threnbath, 1974). Hashem (1983) indicated that 40 percent N may be saved in a maize + cowpea intercropping system. Islam (1982) estimated that 80 percent nitrogen fertilizers might be saved in maize + blackgram intercropping. He found highest LER value (1.55) when maize was intercropping with blackgram at 44,444 maize plants/ha + 1,11,111 blackgram plants/ha with 20 kg N/ha instead of 120 kg N/ha.

The maize yield increased by intercropping 103 percent with cowpeas, 16 to 82 percent with mung, 16 to 42 percent with groundnut and 25 to 68 percent with beans (Gunasema *et al.*, 1979). It was indicated that yields of all legumes decreased in the intercropping system.

The effect of each crop component should be taken into consideration to determine the plant type for intercropping. The cereal crops possess erectophilic leaf architecture where as legume are phanophilic. Most of the solar energy is harvested by a few leaves of a legume where as cereals absorbs solar energy through the canopy as a whole. Cereals are least affected by shortage of solar energy in a cereal-legume intercropping system, as they are generally taller in nature, but cereals having initial faster growth rate which has a shading effect on the legumes exaggerate competitive disadvantage of legumes. Cereals in most cases thus become the dominant crop and the dominated crops give less than their expected yield (Bandyopadhya, 1984)

Hashem (1983) reported that maize yield was reduced in intercropping with cowpea by 19% at 100% maize + 50% cowpea combination but the total yield advantage increased by 25% compared to sole crop of maize. In both the cases, however, It indicated yield reduction of blackgram and cowpea.

Maximum benefit occurs when component crops are sown in wider row spaces for the tall crop component without reducing its plant population. Such spatial arrangement augments the utilization of available space, soil nutrients and solar radiation for the companion crops. Therefore, the technique of "paired row" planting has been developed to harness the maximum advantage from an intercropping system (Singh, 1983).

Mainruzzaman *et al.* (1981) reported several cereal-legume intercrop combinations like wheat + lentil/chickpea, maize + blackgram and maize + groundnut etc. Some of these combinations resulted in increased productivity. Maize-blackgram and maize + cowpea were reported to be good intercrop combinations by Islam (1982) and Hashem (1983), respectively.

Average increase of total grain production ranged from 29.5 to 92.5 percent as a result of maize + legumes (blackgram, greengram and cowpea) intercropping (Kalra and Gangwar, 1980) system. Islam (1982) found 19 and 16 percent yield reduction of maize than a sole maize in maize + blackgram intercropping systems at population levels of 44, 444 maize plants per hectare and 1,11,111 blackgram plants per hectare. But total yield advantage increased by 47 and 55 percent respectively.

Rathore *et al.* (1980) observed in maize + blackgram intercropping system that paired plating of maize at 30/60 cm using the inter paired space for growing blackgram, significantly increased the production and income compared with standard method of planting of maize at 60 cm row spacing.

The yield advantage of intercropping is the best utilization of the environmental resources for growth and development of the crops' components (Willey, 1979 a; Singh, 1981); other possible ways of improving crop productivity may be through better weed control, pest and disease reduction (Moody and Shetty, 1979).

De *et al*. (1978) showed that the total productivity per unit land area could be increased in maize, sorghum and pearl millet when these crops were interplanted with short-duration legumes like mugbean and soybean. They obtained additional yield of 620 and 120 kg per hectare when maize was intercropped with mungbean and soybean, respectively compared to a sole maize crop.

The benefit of cereal-legumes intercropping systems also could be controlled by the quantity of N_2 fixed by component legume crops. The quantity of N_2 fixed by the legumes component in cereal legume intercropping depends on the species, morphology, and density of legume in the mixture, the type of management and the competition abilities of the component crops. Wahua and Miller (1978) reported that, shading by the cereal, reduce both the seed yields and the N_2 fixation potential of the companion legumes. In a sorghum-soybean intercropping system, a tall variety of sorghum reduced soybean yield by 75% and N_2 fixation at the early pod filling stage by 99%.

A proper combination of crops is important for the success of intercropping systems, when two crops are to be grown together. It is imperative that the peak period of growth of the two crops species should not coincide. Crops of varying maturity duration need to be chosen so that quick maturing crops completes its life cycle before the grand period of growth of the other crop starts. However, the yields of both the crops are reduced when grown as mixed or intercropped, compared with when the crops are grown alone but in most cases combined yields per unit area from mixed or intercropping are higher (Saxena, 1972).

Andrews (1972) indicated that this practice provides scope for better utilization of labour, ensures crop productivity, increases farm income and improves nutritional quality of diet for the farm family. The major objectives of intercropping are (i) to produce an additional crop without affecting much the yield of base crop, (ii) to obtain higher total economic returns, (iii) to optimize the use of natural resources including light water and nutrients and (iv) to stabilize the yield of crops (Rahman *et al*. 1982).

In Madhya pradesh in India a mixture of wheat and gram in proportion of 2:1 was found to give the highest net return than other seed rate ratio (Raheja, 1954). Wheat - chickpea was found to be most efficient with 1 irrigation in respect of land equivalent ratio, relative co-efficient, monetary advantage, relative net return and area time-equivalent ratio (Mondal *et al*., 1986).

Chapter 3

Materials and Methods

Chapter 3
Materials and Methods

The experiment was conducted at the Agronomy field at Sher-e-Bangla Agricultural University, Dhaka during the period from March to June, 2010. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout experimental design, intercultural operations, data recording and their analysis.

3.1 Site description

The experiment was conducted in the Sher-e-Bangla Agricultural University farm, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28 (Appendix-I) during the Kharif-I season of 2009.

3.2 Climate and weather

The experimental area was under the sub-tropical climate that characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the Rabi season (October-March). The weather data during the study period of the experimental site is shown in Appendix II.

3.3 Soil

The farm belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. The land was above sea level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field for soil analysis with the cooperation of Soil Resources and Development Institute (SRDI), Dhaka. The physiochemical properties of the soil are presented in Appendix III. From the initial soil analysis it was found that the quantity of total N (%), available P (ppm) and exchangeable K (meq/100 g soil) were below the critical level.

3.4 Experimental treatments

The planting geometry treatments were adjusted through accommodating the rows in five different dimensions; i) planting maize using paired row and single systems ii) changing distance between two adjacent maize paired rows (MPR) left for accommodating mungbean rows (MuR) iii) mungbean row to spacing (Inter-MuR to MuR).

As such the following seven treatments were tested:

T_1 = MPR + 4 MuR using MPR spacing = 37.5 cm, distance between adjacent MPR = 112.5 cm, Inter-MuR spacing = 30 cm.

T_2 = MPR + 4 MuR using MPR spacing = 30 cm, distance between adjacent MPR = 100 cm, Inter-MuR to MuR = 25 cm.

T_3 = MPR + 3 MuR using MPR spacing = 30 cm, distance between adjacent MPR = 100 cm, Inter-MuR to MuR = 30 cm.

T_4 = MPR + 3 MuR using MPR spacing = 25 cm, distance between adjacent MPR = 85 cm, Inter-MuR to MuR = 30 cm.

T_5 = MPR + 3 MuR using MPR spacing = 25 cm, distance between adjacent MPR = 75 cm, Inter-MuR to MuR = 20 cm.

T_6 = MPR + 4 MuR using MPR spacing = 25 cm, distance between adjacent MPR = 85 cm, Inter-MuR to MuR = 17 cm.

T_7 = MPR + 4 MuR using MPR spacing = 37.5 cm, distance between adjacent MPR = 112.5 cm, Inter-MuR to MuR = 25 cm.

T_8 = MPR + 4 MuR using MPR spacing = 30 cm, distance between adjacent MPR = 100 cm, Inter-MuR to MuR = 20 cm.

T_9 = MPR + 3 MuR using MPR spacing = 30 cm, distance between adjacent MPR = 100 cm, Inter-MuR to MuR = 25 cm.

T_{10} = MPR + 3 MuR using MPR spacing = 25 cm, distance between adjacent MPR = 85 cm, Inter-MuR to MuR = 25 cm.

T_{11} = MPR + 2 MuR using MPR spacing = 25 cm, distance between adjacent MPR = 85 cm, Inter-MuR to MuR = 25 cm.

T_{12} = MPR + 3 MuR using MPR spacing = 25 cm, distance between adjacent MPR = 85 cm, Inter-MuR to MuR = 17 cm.

T_{13} = Sole Maize (Row to row spacing = 75 cm).

T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

(Here, MPR = Maize Paired Row and MuR = Mungbean Row)

3.5 Experimental design

The experiment was conducted in a Randomized Complete Block Design (RCBD) with 3 replications.

3.6 Cultural operations

The details of different cultural operations performed during the course of experimentation are given below:

3.6.1 Land preparation

The land was opened on February 25, 2009 by a tractor-drawn disc plough followed by harrowing. Power tiller was used to obtain a good tilth. The land was leveled by ladder and weeds were collected and removed.

3.6.2 Lay out

Lay out of the experiment following RCBD was done on February 27, 2009.

3.6.3 Seed sowing

Maize and mungbean seeds were sown in line on March 1, 2009. V- shaped furrows about 10 cm deep was made at appropriate distances by a small manually drawn furrow opener. Two to three seeds of maize per hill were dibbled at 5 cm depth of the furrows maintaining a hill distance of 25 cm. Mungbean seeds were sown at 5 cm depth in solid lines at required seed rate. The varieties of maize and mungbean used were Bornali and BARImung-5, respectively. Irrigation was applied in the furrows for the better germination of the seeds.

3.6.4 Gap filling and thinning

Mungbean and maize seed germinated four and five days after sowing (DAS), respectively. Gap filling was done on March 13, 2009 (12 DAS). Thinning of excess maize and mungbean plants were done at 21 DAS to keep one plant per hill of maize and 7-10 cm between plants in a mungbean row. After thinning the population density was estimated as follows:

Table: 1. Population estimates of different row arrangements

No. of treatments	spacing for paired row of Maize * (cm)	Spacing between maize paired rows left for mungbean sowing (cm)	No. of Mungbean rows between maize paired rows	Mungbean row to row spacing** (cm)	Maize population density (No./m^2)	Mungbean population density between maize paired rows space (No./m^2)	Mungbean population density including maize paired row's space (No./m^2)
1	37.5	112.5	4	30	2.67	33	21
2	30	100	4	25	3.08	40	25
3	30	100	3	30	3.08	33	21
4	25	85	3	30	3.64	33	24
5	25	85	3	20	3.64	50	24
6	25	85	4	17	3.64	66	30
7	37.5	112.5	4	25	2.67	40	21
8	30	100	4	20	3.08	50	25
9	30	100	3	25	3.08	40	21
10	25	85	3	25	3.64	40	24
11	25	85	2	25	3.64	40	18
12	25	85	3	17	3.64	66	24
13	*Sole maize: spacing 75 × 25 cm, population density = 5.33/ m^2						
14	**Sole mungbean: spacing 30 × 10, population density = 33.33/ m^2						

3.6.5 Weeding

Weeding was done manually on March 21, 2009 (20 DAS) both in sole and intercropped treatments.

3.6.6 Plant protection

Adequate plant protection measures were taken for better establishment of the plants. Vitavax-200 at the rate of 2g per kg seed was used before seed sowing for seed treatment. Diazinon 60 EC at the rate of 2.5 ml per litre, Sumitheon at the rate of 2 ml per litre water at 15 and 35 DAS respectively were applied to prevent mungbean plants from the attach of caterpillar, pod borer etc. Mild infestation of mosaic virus was noticed in mungbean and maize was free from any disease. Earthing-up was practiced against lodging of maize plants.

3.6.7 Application of fertilizer

Maize plants received a uniform application of 300-216-120-144-7 kg/ha of Urea, TSP, MOP, Gypsum, and Boric acid, respectively. Sole mungbean received 30 kg nitrogen per hectare. Half amount of urea and full quantity of TSP, MOP, Gypsum, and Boric acid were mixed with soil of maize and mungbean treatments at the time of sowing. The remaining quantity of urea was applied in maize rows in two equal splits at 25 and 45 DAS as side dressing. The sole mungbean received 30 kg N/ha as basal application. Additional fertilizer was not applied for mungbean as intercrop.

3.7 Data recorded at harvest

3.7.1 Crop characters

For determining the crop characters 10 plants each of mungbean and maize from each plot were collected. The following data were recorded from the sampled plants.

Data for Maize

i) Plant height (cm)

ii) Number of leaves/plant

iii) Leaf area (cm^2)

iv) Fodder weight/plant (g)

v) Fodder weight/ha (kg)

vi) Dry weight/plant (g)
vii) Cob length (cm)
viii) Number of grains per cob
ix) 1000- grain weight (g)
x) Grain yield (kg/ha)
xi) Harvest index (%)

Data for Mungbean

i) Plant height (cm)
ii) Number of branches/plant
iii) Leaf area/plant (cm^2)
iv) Dry weight/plant (g)
v) Number of pods per plant
vi) Number of seeds per pod
vii) 1000-seed weight (g)
viii) Seed yield (kg/ha)

3.7.2 Grain yield

An area of 5 m^2 (2.5m × 2m) was harvested from both sole and intercropped treatments of mungbean and maize. The harvested area included different maize and mungbean rows in sole and intercrop treatment. Mungbean was harvested in two times at 64 and 79 DAS. Maize was harvested at 99 DAS. The pods and cobs were threshed. Grains were cleaned and dried in the sun. The grain weight was adjusted to 12% moisture and per plot grain yield of maize and mungbean were recorded. Maize stover was dried and per plot weight was recorded. The grain yield of maize and mungbean and stover yield of maize from each plot were converted into per hectare yield.

3.7.3 Equivalent yield

Yield of individual crop was converted into equivalent yield by converting yield of intercrops into the yield of sole crops on the basis of prevailing Market prices of individual crop (Anjaneyulu *et al*., 1982). Market prices are presented in the table.

$$\text{Maize equivalent yield} = Y_m + \frac{Y_i \times P_i}{P_m}$$

Where,

Ym = Yield of maize (kg/ha)

Yi = Yield of intercrop mungbean (kg/ha)

Pi = Price of mungbean (Tk 70.00/ha)

Pm = Price of maize (Tk 15.00/ha).

3.8 Harvest index of maize

Harvest index of maize was calculated by following formula:

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield (excluding root)}} \times 100$$

3.9 Relative Yield

Relative yield is the ratio between yield of component crops and yield of sole crop.

$$\text{Relative Yield} = \frac{\text{Yield of component crop}}{\text{Yield of sole crop}}$$

3.10 Land equivalent ratio (LER)

LER was calculated by the following formula as given by Willey (1979 b).

Where,	Yml	=	Yield of maize when intercropped with legume
	Ym	=	Yield of sole maize
	Ylm	=	Yield of legume when intercropped with maize
	Yl	=	Yield of sole legume

3.11 Economics

The total man hours used for the different field operations including harvesting and threshing were recorded on the basis of fix area and time requirement that finally converted to Tk/ha along with the cost of variable input to determine the variable cost of different treatments. The cost and monetary return of different treatments were computed on the basis of prevailing market price of maize and mungbean grains.

3.12 Benefit cost ratio (BCR)

Benefit cost ratio (BCR) of different treatments were calculated as follows:

$$BCR = \frac{\text{Gross return (Tk/ha)}}{\text{Cost of cultivation (Tk/ha)}}$$

3.13 Statistical analysis

The data of each plot were analyzed with the computer-based software MSTATC and mean separation was done following Least Significant Difference (LSD) test.

Chapter 4

Results and Discussion

CHAPTER 4

Results and Discussion

The results obtained from present study for different crop characters, yields and other analyses have been presented and discussed in this chapter.

4.1 Maize

4.1.1 Plant height

The height of maize was greatly affected by different treatments (Fig. 1) at different days after sowing (DAS) under the present study. It was observed that the sole treatment (T_{13}) showed the tallest plant (91.33, 164.30 and 225.20 cm at 30 and 60 DAS and at harvest, respectively). But in intercropped treatments T_{12} showed tallest plant (90.26, 162.80 and 223.10 cm at 30, 60 and at harvest, respectively) which was closely followed by treatment T_{11}. On the other hand the height of maize in treatment T_1 was the shortest (76.36, 141.20 and 181.20 cm at 30, 60 DAS and at harvest respectively). The results obtained from all other treatments were different from the highest and lowest plant height.

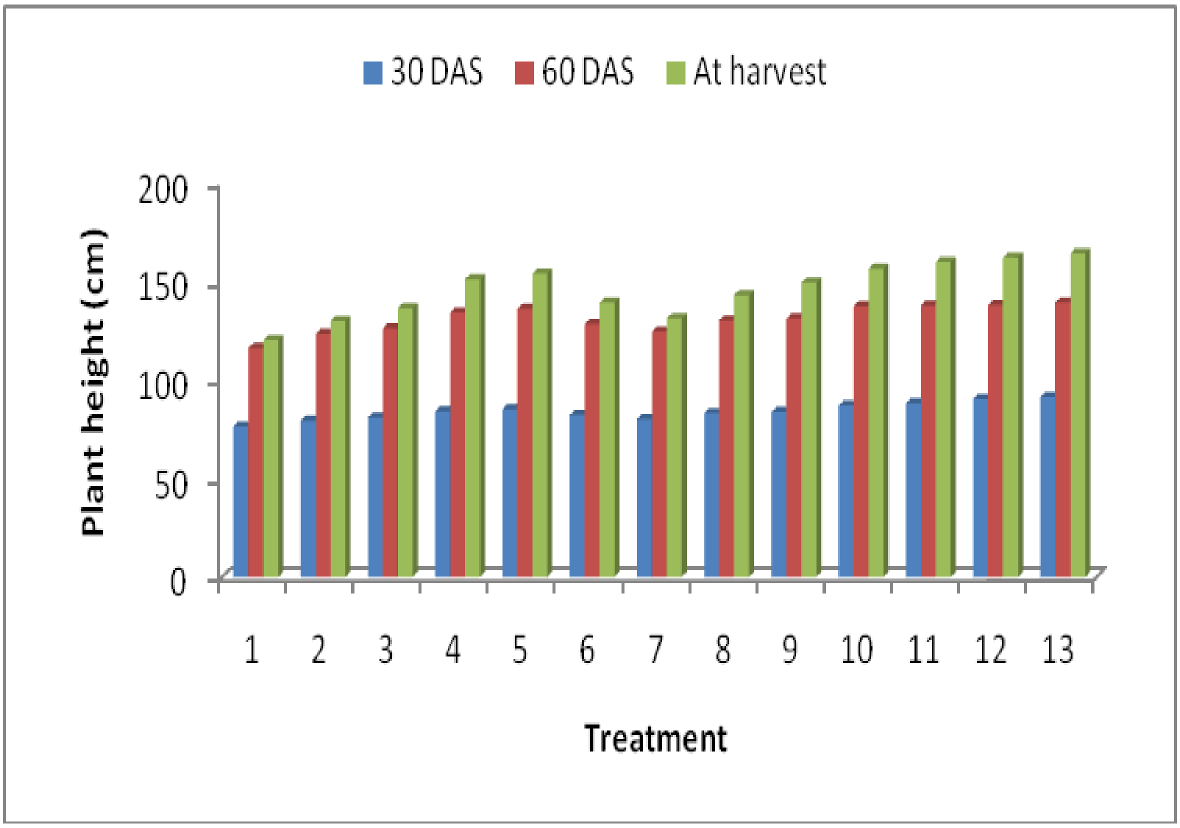

Fig 1. Performance of maize – mungbean intercropping on plant height of maize Under different planting geometry at different day after sowing (DAS)

	i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)
T_1	4	37.5	112.5	30	T_5	3	25	85	20	T_9	3	30	100	25
T_2	4	30	100	25	T_6	4	25	85	20	T_{10}	3	25	85	25
T_3	3	30	100	30	T_7	4	37.5	112.5	25	T_{11}	2	25	85	25
T_4	3	25	85	30	T_8	4	30	100	20	T_{12}	3	25	85	20

i) Number of mungbean rows between adjacent MPR ii) MPR spacing iii) distance between adjacent MPR iv) Inter-MuR spacing; T_{13} = Sole Maize (Row to row spacing = 75 cm); T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

4.1.2 Number of leaves/plant

Number of leaves/plant under the present study was significantly influenced by different treatments (Table 2) at different days after sowing (DAS). The sole treatment of maize (T_{13}) showed the highest number of leaves/plant (5.88, 9.28 and 12.68 at 30, 60 DAS and at harvest respectively). But in intercropped treatments T_{12} showed the highest number of leaves/plant (5.86, 9.12 and 12.61 at 30, 60 and at harvest respectively) followed by treatment T_{10} and T_{11}. On the other hand the lowest number of leaves/plant of maize was in treatment T_1 (5.36, 8.22 and 11.44 at 30, 60 DAS and at harvest respectively) followed by T_2 and T_3. The results obtained from all other treatments were significantly different from the highest and lowest number of leaves /plant.

Table 2. Performance of maize – mungbean intercropping on number of leaves/plant of maize under different planting geometry at different days after sowing (DAS)

Treatment	Number of leaves/plant		
	30 DAS	60 DAS	At harvest
T_1	5.36 g	8.22 h	11.44 h
T_2	5.44 fg	8.36 h	11.64 g
T_3	5.55 ef	8.58 fg	11.75 efg
T_4	5.75 abc	8.81 de	12.33 c
T_5	5.79 ab	8.88 cd	12.35 c
T_6	5.59 de	8.61 ef	11.84 def
T_7	5.51 ef	8.41 gh	11.69 fg
T_8	5.64 cde	8.68 def	11.91 de
T_9	5.70 bcd	8.76 def	12.00 d
T_{10}	5.81 ab	9.02 bc	12.44 bc
T_{11}	5.83 ab	9.09 ab	12.56 ab
T_{12}	5.86 a	9.12 ab	12.61 a
T_{13}	5.88 a	9.28 a	12.68 a
T_{14}	--	--	--
$LSD_{0.05}$	0.1305	0.1846	0.1599
CV (%)	4.55	6.32	5.19

	i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)
T_1	4	37.5	112.5	30	T_5	3	25	85	20	T_9	3	30	100	25
T_2	4	30	100	25	T_6	4	25	85	20	T_{10}	3	25	85	25
T_3	3	30	100	30	T_7	4	37.5	112.5	25	T_{11}	2	25	85	25
T_4	3	25	85	30	T_8	4	30	100	20	T_{12}	3	25	85	20

i) Number of mungbean rows between adjacent MPR ii) MPR spacing iii) distance between adjacent MPR iv) Inter-MuR spacing; T_{13} = Sole Maize (Row to row spacing = 75 cm); T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

4.1.3 Leaf area / plant (cm^2)

Lleaf area/plant (cm^2) was significantly affected by different treatments (Table 3) at different days after sowing (DAS). The sole treatment of maize (T_{13}) showed the highest leaf area/plant (238.20, 571.10 and 682.90 cm^2 at 30, 60 DAS and at harvest respectively). But in intercropped treatments T_{12} showed the highest leaf area/plant (234.40, 563.30 and 672.60 cm^2 at 30, 60 DAS and at harvest respectively). Treatment T_{10} and T_{11} also showed higher leaf area/plant but significantly different from T_{12}. On the other hand the lowest leaf area/plant of maize was in treatment T_1 (207, 478.20 and 571.10 cm^2 at 30, 60 DAS and at harvest respectively). Treatment T_2, T_3 and T_7 also showed lower leaf area/plant but significantly higher than T_1. The results obtained from all other treatments showed intermediate results and those were significantly different from the highest and lowest leaf area/plant.

Table 3. Performance of maize – mungbean intercropping on leaf area of maize under different planting geometry at different days after sowing (DAS)

Treatment	Leaf area / plant (cm2)		
	30 DAS	60 DAS	At harvest
T_1	207.00 j	478.20 l	571.10 k
T_2	213.30 i	486.70 k	583.70 j
T_3	216.60 hi	500.10 j	603.80 i
T_4	225.20 ef	530.00 f	638.90 f
T_5	227.70 de	538.20 e	643.20 e
T_6	219.10 gh	505.30 i	610.00 h
T_7	215.10 i	480.20 l	600.90 i
T_8	222.20 fg	515.50 h	630.90 g
T_9	224.00 f	522.20 g	636.40 f
T_{10}	230.60 cd	545.50 d	647.20 d
T_{11}	232.20 bc	551.80 c	654.30 c
T_{12}	234.40 b	563.30 b	672.60 b
T_{13}	238.20 a	571.10 a	682.90 a
T_{14}	--	--	--
$LSD_{0.05}$	3.419	3.849	3.852
CV (%)	8.58	7.14	5.89

	i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)
T_1	4	37.5	112.5	30	T_5	3	25	85	20	T_9	3	30	100	25
T_2	4	30	100	25	T_6	4	25	85	20	T_{10}	3	25	85	25
T_3	3	30	100	30	T_7	4	37.5	112.5	25	T_{11}	2	25	85	25
T_4	3	25	85	30	T_8	4	30	100	20	T_{12}	3	25	85	20

i) Number of mungbean rows between adjacent MPR ii) MPR spacing iii) distance between adjacent MPR iv) Inter-MuR spacing; T_{13} = Sole Maize (Row to row spacing = 75 cm); T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

4.1.4 Fodder weight/plant (g)

Maize fodder weight ranged from 312-466 g/plant (Fig 2). The highest fodder weight was shown by T_7. Treatments $T_{8,}$ $T_{10,}$ T_{11} and T_{13} shwoed identical fodder weight per plant but those were lower thanT_7 treatment. Other treatments showed lower values with no appreciable differences among them due to intercropping.

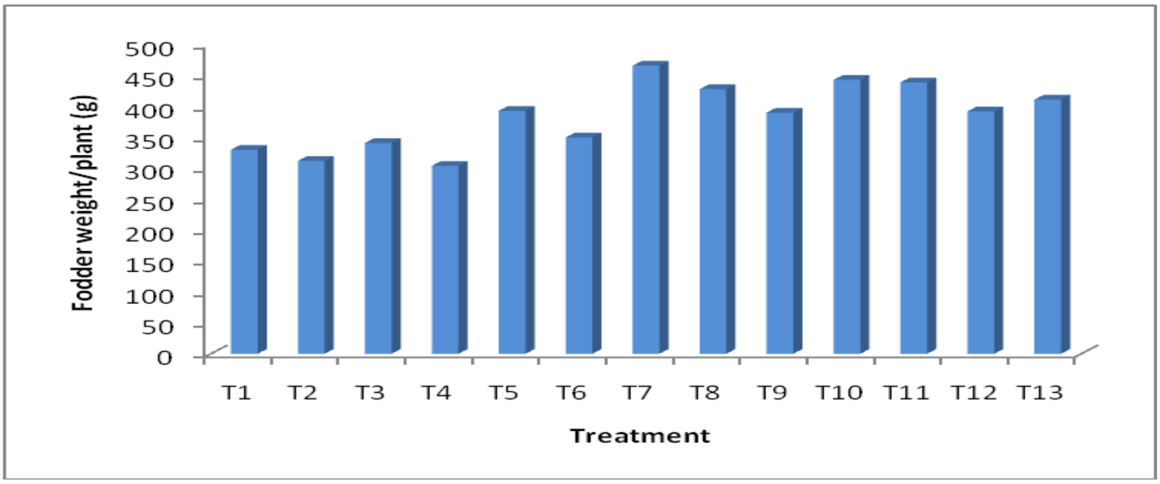

Fig 2: Effect of different row arrangements in maize-mungbean intercropping on the per plant fodder weight (g/plant) of maize.

	i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)
T_1	4	37.5	112.5	30	T_5	3	25	85	20	T_9	3	30	100	25
T_2	4	30	100	25	T_6	4	25	85	20	T_{10}	3	25	85	25
T_3	3	30	100	30	T_7	4	37.5	112.5	25	T_{11}	2	25	85	25
T_4	3	25	85	30	T_8	4	30	100	20	T_{12}	3	25	85	20

i) Number of mungbean rows between adjacent MPR ii) MPR spacing iii) distance between adjacent MPR iv) Inter-MuR spacing; T_{13} = Sole Maize (Row to row spacing = 75 cm); T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

4.1.5 Fodder weigth t/ha (ton)

Maize fodder weight/ha ranged from 8.995-20.645 t/ha (Fig 3). In intercropping maize fodder weight/ha decreased drastically from 33-56% due to using paired rows of maize to incorporate mungbean rows. The highest fodder weight was obtained from T_{13} (sole maize). This was obvious as this treatment had the highest population density (5.33 plants/m^2) than others (2.67-3.64) (Table 1). Among the intercropping treatments, T_{10}, T_{11}, and T_{12} showed comparatively higher weight t/ha but those werw lower than sole maize. This may also be attributed to the higher population density of maize (3.64/m^2) that resulted due to narrowing the spacing between the paired rows of maize. Significantly the lowest fodder weight was found in T_1 which is again attributed to the lower population density (2.67/m^2) that resulted owing to the use of widest space (11.25 cm) between the paired maize rows.

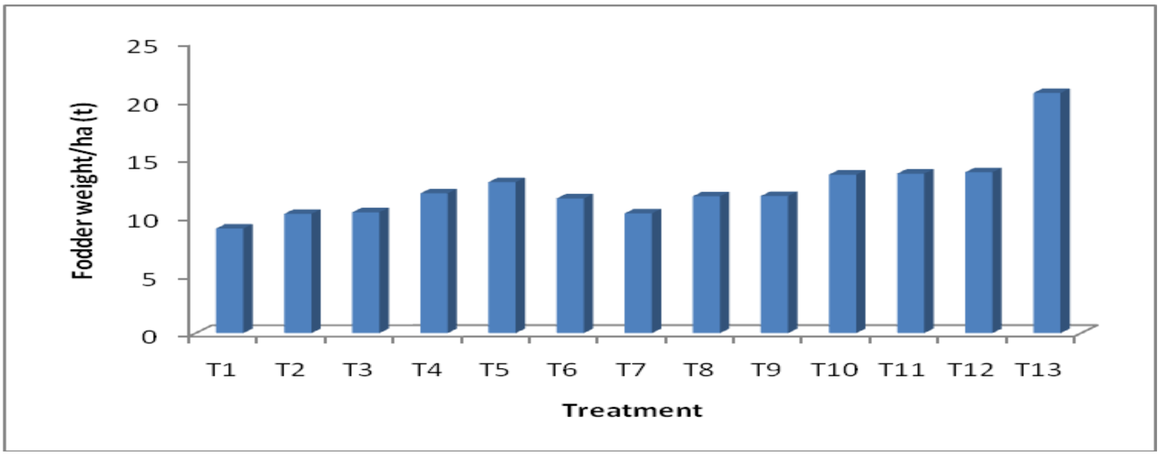

Fig 3: Effect of different row arrangements in maize-mungbean intercropping on the per hectare fodder weight (t/ha) of maize

	i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)
T_1	4	37.5	112.5	30	T_5	3	25	85	20	T_9	3	30	100	25
T_2	4	30	100	25	T_6	4	25	85	20	T_{10}	3	25	85	25
T_3	3	30	100	30	T_7	4	37.5	112.5	25	T_{11}	2	25	85	25
T_4	3	25	85	30	T_8	4	30	100	20	T_{12}	3	25	85	20

i) Number of mungbean rows between adjacent MPR ii) MPR spacing iii) distance between adjacent MPR iv) Inter-MuR spacing; T_{13} = Sole Maize (Row to row spacing = 75 cm); T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

4.1.6 Dry weight/plant (g)

Dry weight/plant (g) was significantly influenced by different treatments (Table 4) at different days after sowing (DAS). The sole treatment of maize (T_{13}) showed the highest dry weight/plant (41.03, 70.11 and 90.88 g at 30, 60 DAS and at harvest respectively). But among the intercropped treatments T_{12} showed the highest dry weight/plant (38.06, 65.38 and 85.34 g at 30, 60 and at harvest respectively). Treatment T_4, T_5, T_{10} and T_{11} also showed higher dry weight/plant but those were significantly lower than T_{12}. On the other hand the lowest dry weight/plant of maize was found in treatment T_1 (32.02, 48.35 and 70.32 g at 30, 60 DAS and at harvest respectively). Treatment T_2, T_3 and T_7 also showed lower dry weight/plant but those were significantly higher than T_1.

Table 4. Performance of maize – mungbean intercropping on dry weight/plant of maize under different planting geometry at different days after sowing (DAS)

Treatment	Dry weight/plant (g)		
	30 DAS	60 DAS	At harvest
T_1	32.02 f	48.35 m	70.32 m
T_2	33.03 f	50.16 l	72.08 l
T_3	33.34 def	53.44 j	74.64 j
T_4	37.22 b	62.42 d	81.36 f
T_5	37.68 b	64.24 c	83.28 e
T_6	34.88 cde	55.02 i	75.39 i
T_7	33.18 ef	52.18 k	73.33 k
T_8	35.03 cd	55.08 h	77.18 h
T_9	35.33 c	56.18 g	79.14 g
T_{10}	36.21 bc	59.14 f	82.06 d
T_{11}	37.14 b	60.89 e	87.54 c
T_{12}	38.06 b	65.38 b	85.34 b
T_{13}	41.03 a	70.11 a	90.88 a
T_{14}	--	--	--
$LSD_{0.05}$	1.690	1.045	1.121
CV (%)	5.47	7.94	7.46

	i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)
T_1	4	37.5	112.5	30	T_5	3	25	85	20	T_9	3	30	100	25
T_2	4	30	100	25	T_6	4	25	85	20	T_{10}	3	25	85	25
T_3	3	30	100	30	T_7	4	37.5	112.5	25	T_{11}	2	25	85	25
T_4	3	25	85	30	T_8	4	30	100	20	T_{12}	3	25	85	20

i) Number of mungbean rows between adjacent MPR ii) MPR spacing iii) distance between adjacent MPR iv) Inter-MuR spacing; T_{13} = Sole Maize (Row to row spacing = 75 cm); T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

4.1.7 Cob length (cm)

Cob length was significantly influenced by different treatments (Table 5) . It was observed that the longest cob (18.85 cm) was recorded in sole treatment T_{13}. But among the intercropped treatments T_{12} showed the highest cob length (17.91 cm) which was statistically identical with T_{11} and T_{10}. Treatment T_4, T_5 and T_9 also showed higher cob length but those were significantly lower than T_{13}.

On the other hand the lowest cob length (13.78 cm) was observed in treatment T_1. Treatment T_2 and T_3 also showed lower cob length but signicicantly higher than T_1.

4.1.8 Number of grains/cob

Number of grains/cob was significantly influenced by different treatments (Table 5). The highest number of grains/cob (376.70) was recorded in sole treatment T_{13}. But among the intercropped treatments T_{12} showed the highest cob length (335.50) but treatment T_{10} and T_{11} also showed higher number of grains/cob but statistically different from T_{12}. On the other hand the lowest number of grains/cob (188.90) was in treatment T_1. Treatment T_2, T_3 and T_7 also showed lower grain per cob but significantly different from T_1.

4.1.9 Weight of 1000 seeds

Weight of 1000 seeds was significantly influenced by different treatments (Table 5). The highest 1000 seed weight (230.70 g) was recorded in sole treatment ($T_{13)}$. Butamong the intercropped treatments T_{12} showed the highest 1000 seed weight (228.70 g) which was statistically identical with T_{10} (228.60 g) and T_{11} (228.67 g) and statistically similar with T_5 (227.41 g). On the other hand the lowest 1000 seed weight (218.10 g) was recorded in treatment T_1. Treatment T_2 and T_3 also showed lower 1000 seed weight but those were significantly hgher than T_1.

4.1.10 Seed yield (kg/ha)

Different planting geometry of maize mungbean intercropping influenced significantly the grain yield of maize (Table 5). The highest grain yield (4488 kg/ha) was obtained from the T_{13} treatment as sole crop. But in intercropping situations treatment T_{12} produced highest grain yield (3966 kg/ha). Treatment T_{10} and T_{11} were also produced higher grain yield (3858 and 3789 kg/ha respectively) but those were significantly lower than T_{12}. In general, grain yield of maize reduced in intercropping situation compared to the sole maize. On the other hand, the lowest grain yield (2664 kg/ha) was obtained from T_1 where T_2, T_3 and T_7 also showed reduced yield but those were significantly higher than T_1 . This result was in agreement with the findings of Akanda and Quayyum (1982), Gangwar and Kalra (1984) and Akhtaruzzaman (1987). In general, grain yield of maize reduced in intercropping situation compared to the sole maize.

4.1.11 Harvest index (%)

Harvest index of maize was significantly influenced by different treatments (Table 5). It was observed that the maximum harvest index (44.28%) was observed in sole treatment T_{12}. But in intercrop situation it was with T_{13} (41.18%) which was statistically identical with T_{10} and T_{11}. On the other hand the lowest harvest index was obtained from T_1 treatment. T_2 also showed lower harvest index but that was significantly higher than T_1.

Table 5. Performance of maize – mungbean intercropping on yield and yield parameters of maize under different planting geometry

Treatment	Cob length (cm)	Number of grain/cob	1000 seed weight (g)	Seed yield (kg/ha)	Harvest index (%)
T_1	13.78 h	188.90 l	218.10 f	2664 m	30.66 h
T_2	14.68 g	201.70 k	220.40 e	2810 l	33.88 g
T_3	14.91 fg	218.60 i	221.90 de	2886 j	35.20 fg
T_4	16.22 d	301.10 e	226.10 c	3592 f	38.11 cd
T_5	16.88 c	320.20 d	227.41 bc	3672 e	39.65 bc
T_6	15.48 ef	236.90 h	223.70 d	3126 i	36.18 ef
T_7	15.00 fg	208.30 j	222.71 d	2990 k	35.04 fg
T_8	15.89 de	275.30 g	225.50 c	3277 h	37.06 de
T_9	16.04 de	287.40 f	225.90 c	3370 g	37.29 de
T_{10}	17.36 bc	326.10 c	228.60 b	3789 d	40.02 b
T_{11}	17.68 b	326.30 c	228.67 b	3858 c	40.88 b
T_{12}	17.91 b	335.50 b	228.70 b	3966 b	41.18 b
T_{13}	18.85 a	376.70 a	230.70 a	4488 a	44.28 a
T_{14}	--	--	--		--
$LSD_{0.05}$	0.5487	2.446	1.772	13.67	1.768
CV (%)	4.87	6.66	7.89	7.78	5.75

	i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)
T_1	4	37.5	112.5	30	T_5	3	25	85	20	T_9	3	30	100	25
T_2	4	30	100	25	T_6	4	25	85	20	T_{10}	3	25	85	25
T_3	3	30	100	30	T_7	4	37.5	112.5	25	T_{11}	2	25	85	25
T_4	3	25	85	30	T_8	4	30	100	20	T_{12}	3	25	85	20

i) Number of mungbean rows between adjacent MPR ii) MPR spacing iii) distance between adjacent MPR iv) Inter-MuR spacing; T_{13} = Sole Maize (Row to row spacing = 75 cm); T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

4.2 Mungbean

4.2.1 Plant height

Plant height of mungbean was significantly affected by different treatments (Table 6) at different days after sowing (DAS) under the present study. The sole treatment (T_{14}) showed the tallest plant (15.14, 40.17 and 45.28 cm at 20, 40 DAS and at harvest respectively). But in intercropping system T_{12} showed the tallest plant (14.86 cm) which was statistically similar with T_{10} and T_{11} at 20 DAS. But at 40 SAS and at harvest T_{11} showed the tallest plant (39.41 and 44.58 cm at 40 DAS and at harvest respectively). T_7 and T_{10} also showed higher plant height but those were significantly lower than T_{11}. On the other hand the lowest plant height of mungbean was observed in treatment T_6 (13.12, 33.72 and 37.66 cm at 20, 40 DAS and at harvest respectively) .. Mungbean plants showed a tendency to increase plant height in intercropping situations which could be as a result of competition for sunlight and shedding effect of maize plants (Karim *et al*. 1990)

Table 6. Performance of maize – mungbean intercropping on plant height of mungbean under different planting geometry at different days after sowing (DAS)

Treatment	Plant height (cm)		
	20 DAS	40 DAS	At harvest
T_1	13.95 e	37.28 g	41.19 h
T_2	14.30 d	38.28 e	42.31 f
T_3	14.58 bcd	38.61 d	42.54 ef
T_4	14.71 bc	38.50 de	42.38 ef
T_5	13.31 f	35.56 i	39.49 j
T_6	13.12 f	33.72 j	37.66 k
T_7	14.51 cd	39.11 c	43.15 d
T_8	13.91 e	37.61 f	41.55 g
T_9	13.88 e	36.61 h	40.57 i
T_{10}	14.64 bc	39.00 c	43.92 c
T_{11}	14.67 bc	39.51 b	44.58 b
T_{12}	14.86 b	37.89 f	42.68 e
T_{13}	--	--	--
T_{14}	15.14 a	40.17 a	45.28 a
$LSD_{0.05}$	0.2717	0.2820	0.2919
CV (%)	5.68	6.14	7.45

	i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)
T_1	4	37.5	112.5	30	T_5	3	25	85	20	T_9	3	30	100	25
T_2	4	30	100	25	T_6	4	25	85	20	T_{10}	3	25	85	25
T_3	3	30	100	30	T_7	4	37.5	112.5	25	T_{11}	2	25	85	25
T_4	3	25	85	30	T_8	4	30	100	20	T_{12}	3	25	85	20

i) Number of mungbean rows between adjacent MPR ii) MPR spacing iii) distance between adjacent MPR iv) Inter-MuR spacing; T_{13} = Sole Maize (Row to row spacing = 75 cm); T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

4.2.2 Number of branches/plant

Number of branches/plant of mungbean was significantly affected by different treatments (Table 7) .The sole treatment (T_{13}) showed the highest number of branches/plant (1.79, 3.72 and 4.77 at 20, 40 DAS and at harvest respectively). But in intercropping system T_{11} showed the highest number of branches/plant (1.41, 3.34 and 4.36) which was statistically identical with T_9 at all growth stages of mungbean and at the time of harvest, treatment T_3, T_4, T_6, T_7 and T_{10} also showed the alike results. On the other hand the lowest number of branches/plant (0.88, 2.67 and 3.77 at 20, 40 DAS and at harvest respectively) was recorded in treatment T_8 followed by T_5 at 20 and 40 DAS and statistically identical at harvest.

Table 7. Performance of maize – mungbean intercropping on number of branches/plant (mungbean) under different planting geometry at different days after sowing (DAS)

Treatment	Number of branches/plant		
	20 DAS	40 DAS	At harvest
T_1	1.15 cd	3.16 bcd	4.18 bc
T_2	1.00 def	2.96 de	3.94 cd
T_3	1.28 bc	3.28 bc	4.30 b
T_4	1.25 bc	3.22 bc	4.26 b
T_5	0.91 ef	2.78 ef	3.81 d
T_6	1.31 bc	3.29 bc	4.35 b
T_7	1.18 bcd	3.17 bcd	4.23 b
T_8	0.88 f	2.67 f	3.77 d
T_9	1.39 b	3.33 b	4.35 b
T_{10}	1.30 bc	3.23 bc	4.27 b
T_{11}	1.41 b	3.34 b	4.36 b
T_{12}	1.11 cde	3.06 cd	4.10 bc
T_{13}	--	--	--
T_{14}	1.79 a	3.72 a	4.77 a
$LSD_{0.05}$	0.2064	0.2197	0.2323
CV (%)	7.28	6.11	6.98

	i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)
T_1	4	37.5	112.5	30	T_5	3	25	85	20	T_9	3	30	100	25
T_2	4	30	100	25	T_6	4	25	85	20	T_{10}	3	25	85	25
T_3	3	30	100	30	T_7	4	37.5	112.5	25	T_{11}	2	25	85	25
T_4	3	25	85	30	T_8	4	30	100	20	T_{12}	3	25	85	20

i) Number of mungbean rows between adjacent MPR ii) MPR spacing iii) distance between adjacent MPR iv) Inter-MuR spacing; T_{13} = Sole Maize (Row to row spacing = 75 cm); T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

4.2.3 Leaflet area/plant

Leaflet area/plant (cm^2) was significantly affected by different treatments (Table 8 The sole treatment of mungbean (T_{14}) showed the highest leaflet area/plant (20.12, 41.26 and 39.88 cm^2 at 20, 40 DAS and at harvest respectively) and it was statistically identical with intercropped treatment T_{12} which resulted 19.94, 40.98 and 39.67 cm^2 at 20, 40 DAS and at harvest respectively. On the other hand the lowest leaflet area/plant (16.44, 34.91 and 33.04 cm^2 at 20, 40 DAS and at harvest respectively) was recorded in treatment T_2. Treatment T_1, T_3 and T_8 also showed lower leaflet area/plant but significantly higher than T_2. The results obtained from all other treatments showed intermediate results .

Table 8. Performance of maize – mungbean intercropping on leaflet area of mungbean under different planting geometry at different days after sowing (DAS)

Treatment	Leaflet area/plant (cm^2)		
	20 DAS	40 DAS	At harvest
T_1	16.98 e	35.89 f	34.00 g
T_2	16.44 f	34.91 g	33.04 h
T_3	17.03 e	35.88 f	34.01 g
T_4	18.55 c	39.02 c	37.16 cd
T_5	17.82 d	37.67 d	35.78 e
T_6	18.66 c	39.12 c	37.22 cd
T_7	19.15 b	40.04 b	38.18 b
T_8	17.13 e	36.11 f	34.21 g
T_9	18.46 c	38.82 c	36.86 d
T_{10}	17.62 d	37.21 e	35.19 f
T_{11}	18.68 c	39.18 c	37.31 c
T_{12}	19.94 a	40.98 a	39.67 a
T_{13}	--	--	--
T_{14}	20.12 a	41.26 a	39.88 a
$LSD_{0.05}$	0.3412	0.4329	0.3952
CV (%)	8.22	7.56	8.74

	i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)
T_1	4	37.5	112.5	30	T_5	3	25	85	20	T_9	3	30	100	25
T_2	4	30	100	25	T_6	4	25	85	20	T_{10}	3	25	85	25
T_3	3	30	100	30	T_7	4	37.5	112.5	25	T_{11}	2	25	85	25
T_4	3	25	85	30	T_8	4	30	100	20	T_{12}	3	25	85	20

i) Number of mungbean rows between adjacent MPR ii) MPR spacing iii) distance between adjacent MPR iv) Inter-MuR spacing; T_{13} = Sole Maize (Row to row spacing = 75 cm); T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

4.2.4 Fodder weight/plant (g)

Mungbean fresh weight ranged from 31.82-43.14 g/plant (Fig 4). The trend of mungbean per plant fresh weight (fodder weight) although was found to be inconsistent, significantly the highest per plant fresh weight was obtained from T_{14} (Mungbean sole) which was identical with $T_{3,}$ $T_{6,}$ T_9 and T_{12}. The highest value of the sole mungbean may be attributed to the lower population density ($33/m^2$) against those of other treatments (over $40/m^2$) (Table 1).

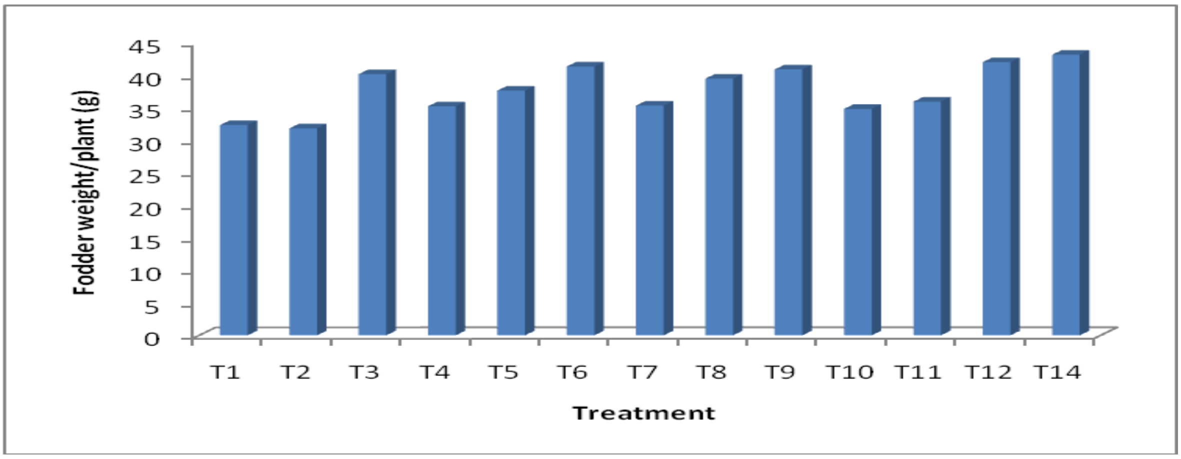

Fig 4: Effect of different row arrangements in maize-mungbean intercropping on the per plant fresh weight of mungbean

	i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)
T_1	4	37.5	112.5	30	T_5	3	25	85	20	T_9	3	30	100	25
T_2	4	30	100	25	T_6	4	25	85	20	T_{10}	3	25	85	25
T_3	3	30	100	30	T_7	4	37.5	112.5	25	T_{11}	2	25	85	25
T_4	3	25	85	30	T_8	4	30	100	20	T_{12}	3	25	85	20

i) Number of mungbean rows between adjacent MPR ii) MPR spacing iii) distance between adjacent MPR iv) Inter-MuR spacing; T_{13} = Sole Maize (Row to row spacing = 75 cm); T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

4.2.5 Fodder weight (kg/ha)

The highest fodder weight or fresh weight/ha of mungbean was obtained in the sole plot (T_{14}) (Fig 5). Intercropping decreased the fodder yield (15-73%). Among the intercropping treatments T_8 showed significantly the higher fodder yield. Appreciably the population density did not have significant effect on the mungbean fodder yield, instead the competition free environment probably helped to gain the highest fodder weight of the sole mungbean.

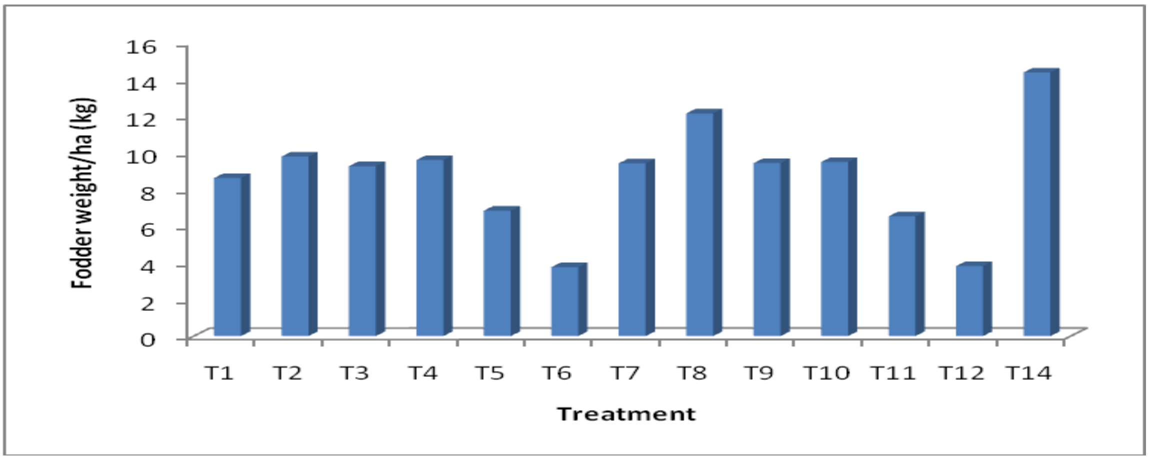

Fig 5: Effect of different row arrangements in maize-mungbean intercropping on the per hectare fresh weight (t/ha) of mungbean

	i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)
T_1	4	37.5	112.5	30	T_5	3	25	85	20	T_9	3	30	100	25
T_2	4	30	100	25	T_6	4	25	85	20	T_{10}	3	25	85	25
T_3	3	30	100	30	T_7	4	37.5	112.5	25	T_{11}	2	25	85	25
T_4	3	25	85	30	T_8	4	30	100	20	T_{12}	3	25	85	20

i) Number of mungbean rows between adjacent MPR ii) MPR spacing iii) distance between adjacent MPR iv) Inter-MuR spacing; T_{13} = Sole Maize (Row to row spacing = 75 cm); T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

4.2.6 Dry weight/plant (g)

Under the present study dry weight/plant (g) was significantly influenced by different treatments (Table 9) based on different planting geometry at different days after sowing (DAS). It was observed that the sole treatment of mungbean (T_{14}) gave the highest dry weight/plant (2.878, 5.74 and 7.79 g at 20, 40 DAS and at harvest respectively) which was statistically identical with intercropped treatments T_7 and T_{11}. On the other hand the lowest dry weight of mungbean (1.04, 2.75 and 4.78 cm2 at 20, 40 DAS and at harvest respectively) was in treatment T_3. The results obtained from all other treatments were significantly different compared to the highest and lowest dry weight/plant.

Table 9. Performance of maize – mungbean intercropping on dry weight/plant of mungbean under different planting geometry at different days after sowing (DAS)

Treatment	Dry weight/plant (g)		
	20 DAS	40 DAS	At harvest
T_1	1.19 e	4.08 e	6.11 e
T_2	1.16 e	4.11 e	6.07 e
T_3	1.04 e	2.75 g	4.78 h
T_4	2.29 b	5.30 b	7.26 b
T_5	1.12 e	4.10 e	6.04 ef
T_6	1.00 e	3.14 f	5.22 g
T_7	2.71 a	5.73 a	7.70 a
T_8	1.02 e	3.89 e	5.83 f
T_9	1.86 c	4.84 c	6.81 c
T_{10}	1.78 c	4.76 c	6.72 c
T_{11}	2.68 a	5.70 a	7.69 a
T_{12}	1.41 d	4.38 d	6.36 d
T_{13}	--	--	--
T_{14}	2.87 a	5.74 a	7.79 a
$LSD_{0.05}$	0.1994	0.2064	0.2132
CV (%)	5.88	4.16	6.23

	i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)
T_1	4	37.5	112.5	30	T_5	3	25	85	20	T_9	3	30	100	25
T_2	4	30	100	25	T_6	4	25	85	20	T_{10}	3	25	85	25
T_3	3	30	100	30	T_7	4	37.5	112.5	25	T_{11}	2	25	85	25
T_4	3	25	85	30	T_8	4	30	100	20	T_{12}	3	25	85	20

i) Number of mungbean rows between adjacent MPR ii) MPR spacing iii) distance between adjacent MPR iv) Inter-MuR spacing; T_{13} = Sole Maize (Row to row spacing = 75 cm); T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

4.2.7 Number of pods/plant

Number of pods/plant was significantly influenced by different treatments (Table 10). The sole treatment of mungbean (T_{14}) showed the highest number of pods/plant (15.67). But in the intercropping treatments the highest number of pods/plant (12.00) was in treatment T_{12} followed by treatments T_6. On the other hand the lowest number of pods/plant (10.78) was in treatment T_2 which was statistically identical with T_8.

4.2.8 Number of seeds/pod

Number of seeds/pods was significantly influenced by different treatments (Table 10). The sole mungbean (T_{14}) showed the highest number of seeds/pods (8.95). But in the intercropping treatments the highest number of seeds/pods (8.87) was recorded in treatment T_3 followed by treatments T_6. On the other hand the lowest number of seeds/pods (7.50) was recorded in treatment T_8.

4.2.9 Weight of 1000 seeds

Weight of 1000 seeds was significantly influenced by different treatments (Table 10). It was observed that the sole treatment of mungbean (T_{14}) showed the highest 1000 seed weight (33.01). But in the intercropping treatments the highest 1000 seed weight (30.77) was recorded in treatment T_{11} which was statistically identical with treatments T_{10}. On the other hand the lowest 1000 seed weight (28.80) was recorded in treatment T_8.

4.2.10 Seed yield

Seed yield was significantly influenced by different treatments (Table 10) .The sole treatment of mungbean (T_{14}) gave the highest seed yield (1280 kg/ha). But in the intercropping treatments the highest seed yield (754.00 kg/ha) was recorded in treatment T_{10}. On the other hand the lowest seed yield (278.00 kg/ha) was recorded in treatment T_6. The results obtained from all other treatments were significantly different compared to highest and lowest seed yield. Reduced yield of intercropped also been reported by Gunasema *et al.* (1979). Though planting systems of maize did not have any significant difference on mungbean grain yield under intercropped situation but it appears that mungbean grain yield was slightly more in paired row planting than uniform row planting system.

Table 10. Performance of maize – mungbean intercropping on yield and yield parameters of mungbean under different planting geometry

Treatment	Number of pods/plant	Number of seeds/pod	1000 seed weight (g)	Seed yield (kg/ha)
T_1	11.00 g	7.97 f	29.67 ef	546 j
T_2	10.78 h	7.77 g	29.53 f	618 g
T_3	11.67 de	8.87 ab	29.17 g	634 f
T_4	11.33 f	8.07 ef	29.04 gh	637 f
T_5	11.22 f	8.20 e	29.90 d	660 e
T_6	11.89 bc	8.70 bc	29.56 f	917 b
T_7	11.78 cd	7.97 f	30.39 c	599 h
T_8	10.67 h	7.50 h	28.80 i	576 i
T_9	11.78 cd	8.67 c	28.99 h	622 g
T_{10}	11.34 f	8.40 d	30.65 b	701 c
T_{11}	11.56 e	8.57 cd	30.77 b	549 j
T_{12}	12.00 b	7.88 fg	29.82 de	677 d
T_{13}	--	--	--	--
T_{14}	15.67 a	8.95 a	33.01 a	1280 a
$LSD_{0.05}$	0.1846	0.1767	0.1599	6.765
CV (%)	4.52	6.32	6.77	7.36

	i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)
T_1	4	37.5	112.5	30	T_5	3	25	85	20	T_9	3	30	100	25
T_2	4	30	100	25	T_6	4	25	85	20	T_{10}	3	25	85	25
T_3	3	30	100	30	T_7	4	37.5	112.5	25	T_{11}	2	25	85	25
T_4	3	25	85	30	T_8	4	30	100	20	T_{12}	3	25	85	20

i) Number of mungbean rows between adjacent MPR ii) MPR spacing iii) distance between adjacent MPR iv) Inter-MuR spacing; T_{13} = Sole Maize (Row to row spacing = 75 cm); T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

4.3 Evaluation of intercropping system (based on grain production)

Total land productivity is a basic consideration in evaluating intercropping system where land holdings are very meager. For this purpose, relative yields, maize equivalent yield, land equivalent ratio (LER), net monetary return per hectare and benefit cost ratio could be the better indicators of the different row management of crops. These were computed and presented in Table 11 and 12 and illustrated under different heads.

4.3.1 Relative Yield

In all the intercrop treatments, relative yield of maize was reduced (Table 11). The extent of yield reduction was more observed in intercropping treatments where sole crop showed higher yield. However, in intercropping T_{12} showed highest maize relative yield (0.88) where the lowest (0.59) in treatment T_1. Relative yield of mungbean in intercropping situation were lower than that of sole mungbean. The intercropping treatment T_2, T_7 and T_{10} showed better relative yield of mungbean than the others. In intercrop treatments the yield reduction in maize and mungbean might be due to inter and intra plant competition or antagonistic relationship between maize and mungbean. This result was in conformity with Hoque *et al.* (1980) and Hashem (1983).

4.3.2 Maize equivalent yield

Comparatively higher maize equivalent yields were recorded for all the intercropping treatments considering the sole maize yield (Table 11). The highest maize equivalent (7307.67 kg/ha) was obtained from the treatment T_{10}. The next higher maize equivalent yield (6966.00 kg/ha) was obtained from sole maize treatment (T_4). On the other hand the lowest maize equivalent yield (4423.33 kg/ha) was obtained from T_6.

4.3.3 Land equivalent ratio (LER)

The difference between actual and expected yield (where LER=1) compute an idea of a relative yield advantage in an intercropping system is expressed as LER. Table 11 showed that a yield advantage was obtained from the intercropping treatments except T_6. Intercropping maize with mungbean at different planting geometry gave LER values ranging from 0.91 to 1.43. Maximum LER (1.43) was obtained from T_{10} which means that by intercropping maize and mungbean under initiated planting system of the treatment could produce 3789 kg of maize and 754 kg of mungbean from one hectares of land instead of growing them separately in 1.43 hectares of land to obtain the same total yield. In other words, by intercropping maize with mungbean the land use efficiency was increased by 43%. The higher LER in intercrop treatments also indicates that the mungbean could be intercropped with maize for higher production and better utilization of resources. Similar result also had been reported from maize + mungbean intercropping by Ahmed *et al*. (2000 b); Polthanee and Changsri (1999); Kalra and Gangwar (1980).

Table 11. Evaluation of intercropping system showing relative yields, maize equivalent yield and land equivalent ratio of different planting geometry

Treatments	Maize		Mungbean		Maize equivalent yield (kg/ha)	LER
	Grain yield (kg/ha)	Relative yield	Seed yield (kg/ha)	Relative yield		
T_1	2664	0.59	694	0.54	5902.67	1.14
T_2	2810	0.63	760	0.59	6356.67	1.22
T_3	2886	0.64	695	0.54	6129.33	1.19
T_4	3592	0.80	723	0.56	6966.00	1.37
T_5	3672	0.82	497	0.39	5991.33	1.21
T_6	3126	0.70	278	0.22	4423.33	0.91
T_7	2990	0.67	759	0.59	6532.00	1.26
T_8	3277	0.73	707	0.55	6576.33	1.28
T_9	3370	0.75	714	0.56	6702.00	1.31
T_{10}	3789	0.84	754	0.59	7307.67	1.43
T_{11}	3858	0.86	551	0.43	6429.33	1.29
T_{12}	3966	0.88	287	0.22	5305.33	1.11
T_{13}	4488	1.00	--	--	--	1.00
T_{14}	--	--	1280	1.00	--	--

	i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)
T_1	4	37.5	112.5	30	T_5	3	25	85	20	T_9	3	30	100	25
T_2	4	30	100	25	T_6	4	25	85	20	T_{10}	3	25	85	25
T_3	3	30	100	30	T_7	4	37.5	112.5	25	T_{11}	2	25	85	25
T_4	3	25	85	30	T_8	4	30	100	20	T_{12}	3	25	85	20

i) Number of mungbean rows between adjacent MPR ii) MPR spacing iii) distance between adjacent MPR iv) Inter-MuR spacing; T_{13} = Sole Maize (Row to row spacing = 75 cm); T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

4.4 Economical profitability

4.4.1 Gross return

Total gross return (Tk 109615.00/ha) was the highest in the treatment T_{10} followed by 104490.00 Tk/ha and 100530.00 Tk/ha respectively in the treatment T_4 and T_9 respectively (Table 12). Both the sole crop of maize and mungbean fail to show higher gross return than intercropped situation. This was due to additional benefit from mungbean without hampering the grain yield of maize. Though mungbean price is higher but fail to show higher gross return in sole situation.

4.4.2 Total variable cost

Cost of sole crop cultivation was lower than intercropping treatments. The highest total cost of cultivation (Tk 42000.00/ha) was found in treatment T_6 while the lowest was in (Tk 3300.00/ha) in T_{14} (sole mungbean). The higher cost was involved in treatment T_6 due to planting system (Table 12).

4.4.3 Net return

The highest net return over variable cost was Tk 69615.00/ha recorded in T_7 though higher cost was involved. The second highest net return Tk 64990.00/ha was recorded in T_4. The lowest net return was Tk 324350.00/ha obtained from T_6 (Table 12). So from monetary point of view, the T_7 was the best intercrop system under the present study.

4.4.4 Benefit cost ratio (BCR)

The highest BCR (2.74) was obtained from T_7. The second highest BCR 2.71 was in T_{14}. The lowest BCR (1.58) was obtained from T_6 (Table 12). Monetary advantages were also obtained by Kalra and Gangwar (1980), Rahman *et al.* (1982), Akanda and Quayyum (1982), Bandyopaydhya (1984) and Akhtaruzzaman (1987)) from intercrop combinations of different crops. It is noted that MPR + 5 rows of mungbean with 60 kg N/ha showed lower BCR than sole mungbean and sole maize in paired rows.

Table 12. Economical profitability showing economic analyses of different treatments in maize mungbean intercropping systems

Treatment	Grain yield (kg/ha)		Gross return (Tk/ha)			Total cost of cultivation (Tk/ha)	Net Return (Tk/ha)	BCR
	Maize (1)	Mungbean (2)	Maize* (3)	Mungbean** (4)	Total 5= (3+4)	(6)	7 = (5-6)	8=(5/6)
T_1	2664	694	39960	48580	88540	36300	52240	2.44
T_2	2810	760	42150	53200	95350	38000	57350	2.51
T_3	2886	695	43290	48650	91940	36800	55140	2.50
T_4	3592	723	53880	50610	104490	39500	64990	2.65
T_5	3672	497	55080	34790	89870	41500	48370	2.17
T_6	3126	278	46890	19460	66350	42000	24350	1.58
T_7	2990	759	44850	53130	97980	38100	59880	2.58
T_8	3277	707	49155	49490	98645	39300	59345	2.51
T_9	3370	714	50550	49980	100530	37800	62730	2.66
T_{10}	3789	754	56835	52780	109615	40000	69615	2.74
T_{11}	3858	551	57870	38570	96440	39600	56840	2.43
T_{12}	3966	287	59490	20090	79580	41300	38280	1.93
T_{13}	4488	--	67320	--	67320	34600	32720	1.95
T_{14}	--	1280	--	89600	89600	33000	56600	2.71

* Price of maize seeds = Tk. 15.00/kg; ** Price of mungbean seeds = Tk. 70.00/kg

	i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)		i	ii(cm)	iii(cm)	iv(cm)
T_1	4	37.5	112.5	30	T_5	3	25	85	20	T_9	3	30	100	25
T_2	4	30	100	25	T_6	4	25	85	20	T_{10}	3	25	85	25
T_3	3	30	100	30	T_7	4	37.5	112.5	25	T_{11}	2	25	85	25
T_4	3	25	85	30	T_8	4	30	100	20	T_{12}	3	25	85	20

i) Number of mungbean rows between adjacent MPR ii) MPR spacing iii) distance between adjacent MPR iv) Inter-MuR spacing; T_{13} = Sole Maize (Row to row spacing = 75 cm); T_{14} = Sole Mungbean (Row to row spacing = 30 cm).

Chapter 5

Summary and Conclusion

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The experiment was conducted at the Agronomy field at Sher-e-Bangla Agricultural University, Dhaka during the period from March to June, 2010 to study the effect of mungbean with maize under different planting geometry. The varieties of maize and mungbean used were Barnali and BARImung-5, respectively. The experiment was conducted in a Randomized Complete Block Design (RCBD) with 3 replications. Fourteen treatments viz, T_1 = 2 MaR + 4 MuR + 2 MaR + 4 MuR and so on (MaR to MaR = 37.5 cm, MaR to MuR = 11.25 cm, MuR to MuR = 30 cm), T_2 = 2 MaR + 4 MuR + 2 MaR + 4 MuR and so on (MaR to MaR = 30 cm, MaR to MuR = 12.5 cm, MuR to MuR = 25 cm), T_3 = 2 MaR + 3 MuR + 2 MaR + 3 MuR and so on (MaR to MaR = 30 cm, MaR to MuR = 20 cm, MuR to MuR = 30 cm), T_4 = 2 MaR + 3 MuR + 2 MaR + 3 MuR and so on (MaR to MaR = 25 cm, MaR to MuR = 12.5 cm, MuR to MuR = 30 cm), T_5 = 2 MaR + 3 MuR + 2 MaR + 3 MuR and so on (MaR to MaR = 25 cm, MaR to MuR = 17.5 cm, MuR to MuR = 20 cm), T_6 = 2 MaR + 4 MuR + 2 MaR + 4 MuR and so on (MaR to MaR = 25 cm, MaR to MuR = 12.5 cm, MuR to MuR = 20 cm), T_7 = 2 MaR + 4 MuR + 2 MaR + 4 MuR and so on (MaR to MaR = 37.5 cm, MaR to MuR = 18.75 cm, MuR to MuR = 25 cm), T_8 = 2 MaR + 4 MuR + 2 MaR + 4 MuR and so on (MaR to MaR = 30 cm, MaR to MuR = 12.5 cm, MuR to MuR = 20 cm), T_9 = 2 MaR + 3 MuR + 2 MaR + 3 MuR and so on (MaR to MaR = 30 cm, MaR to MuR = 25 cm, MuR to MuR = 25 cm), T_{10} = 2 MaR + 3 MuR + 2 MaR + 3 MuR and so on (MaR to MaR = 25 cm, MaR to MuR = 17.5 cm, MuR to MuR = 25 cm), T_{11} = 2 MaR + 2 MuR + 2 MaR + 2 MuR and so on (MaR to MaR = 25 cm, MaR to MuR = 30 cm, MuR to MuR = 25 cm), T_{12} = 2 MaR + 3 MuR + 2 MaR + 3 MuR and so on (MaR to MaR = 25 cm, MaR to MuR = 22.5 cm, MuR to MuR = 20 cm), T_{13} = Sole Maize (MaR to MaR = 75 cm) and T_{14} = Sole Mungbean (MuR to MuR = 30 cm) where MaR = Maize Row and MuR = Mungbean Row were considered for the present study.

The growth, yield and yield contributing characters of maize were significantly influenced by intercropping mungbean with maize. The highest value of different parameters like number of leaves/plant (12.68), leaf area/plant (682.90 cm^2), fodder weight/ha (20.65 t/ha), dry weight/pant (90.88 g), cob length (18.85 cm), number of grains/cob (376.70), 1000 seed weight (230.70 g), yield (4488 kg/ha) and harvest index (44.28%) were obtained in sole maize treatment. But in the intercropping treatments the highest plant height (162.10 cm), number of leaves/plant (12.61), leaf area/plant (672.60 cm^2), fodder weight/ha (13.83 t), dry weight/pant (85.34 g), cob length (17.91 cm), number of grains/cob (335.50), 1000 seed weight (228.70 g), yield (3966 kg/ha) and harvest index (41.18%) were obtained in the treatment T_{12}. On the other hand the lowest plant height (120.20 cm), number of leaves/plant (11.44), leaf area/plant (571.10 cm^2), fodder weight/ha (9.00 t), dry weight/pant (70.32 g), cob length (13.78 cm), number of grains/cob (188.90), 1000 seed weight (218.10 g), yield (2664 kg/ha) and harvest index (30.66%) were obtained in treatment T_1. But in fodder weight/plant the highest (466 g) and lowest (304 g) were obtained from T_7 and T_4 respectively.

The growth, yield and yield contributing characters of mungbean were significantly influenced by intercropping mungbean with maize. The highest values of different parameters likes number of branches/plant (4.77), leaf area/plant (39.88 cm^2), fodder weight/plant (43.14 g), fodder weight/ha (14.38 t), dry weight/pant (7.79 g), number of pods/plant (15.67), number of seeds/pod (8.95), 1000 seed weight (33.01 g), yield (1280.0 kg/ha) were obtained in sole mungbean treatment. But in the intercropping treatments the highest results of plant height (44.58 cm), number of branches/plant (4.36) and 1000 seed weight (30.77 g) were achieved from T_{11}, and other parameters; dry weight/pant (7.70 g) from T_7, fodder weight/ha (12.14 t) from T_8, leaf area/plant (39.67 cm^2) and number of pods/plant (12.00) from T_{12}, number of seeds/pod (8.87) from T_3, and fodder weight/plant (41.33 g) and seed yield (917.00 kg/ha) from T_6 were obtained. On the other hand the lowest results of plant height (37.66 cm) and fodder weight/ha (3.76 t) from T_6, number of branches/plant (3.77) from T_8, leaflet area/plant (33.04 cm^2) and fodder weight/plant (31.82 g) from T_2, dry weight/pant (4.78 g) from T_3, number of pods/plant (10.67), number of seeds/pod (7.50) and 1000 seed weight (28.80 g) from T_8 and yield (546 kg/ha) from T_1 were obtained.

The intercropping systems were evaluated on the basis of relative yield, maize equivalent yield, land equivalent ratio (LER), net monetary returns per hectare and BCR. Relative yield of maize and mungbean revealed that both the components crops in intercropped situation have slight negative effect on their individual yield but their combined yield was higher. Highest LER (1.43) and maize equivalent yield (7307.67 kg/ha) were found in T_{10} where the lowest LER (0.91) and maize equivalent yield (4423.33 kg/ha) were in T_6.

Economic analysis of the different treatments showed that highest gross return (Tk. 109615.00/ha), highest net return (Tk. 69615.00/ha) and BCR (2.74) were also found in T_{10} where the lowest (Tk. 66350.00, Tk. 24350.00 and 1.58 respectively) were obtained by $T_{6.}$

By intercropping of 2 MaR + 3 MuR + 2 MaR + 3 MuR and so on (MaR to MaR = 25 cm, MaR to MuR = 17.5 cm, MuR to MuR = 25 cm) (T_{10}) gave comparatively higher net monetary return compared to that obtained from other intercropping and monoculture of maize and mungbean. However, these results need to be verified further.

From the findings of the present investigation the following conclusion can be drawn:

- Higher total grain productivity was possible in intercropped with mungbean with maize by utilizing the same land in same time.
- Mention the row arrangement system offered the highest land utilization compared to sole one.

- Maize and mungbean intercrop increase total yield than individual yield of maize and mungbean.
- By intercropping of 2 MaR + 3 MuR + 2 MaR + 3 MuR and so on (MaR to MaR = 25 cm, MaR to MuR = 17.5 cm, MuR to MuR = 25 cm) could be viable from economic point of view.

Recommendation

Three row-mungbean accommodated at the space of 85 cm left between maize paired rows' showed the highest per hectare fresh weight and seed yield of mungbean, combined fresh weight and land equivalent ratio. It may be concluded that this planting geometry could be followed to intercrop mungbean with maize. However, in this study plant to plant distance within the row of maize was 25 cm. So, it is essential to examine lower plant to plant distances in future studies.

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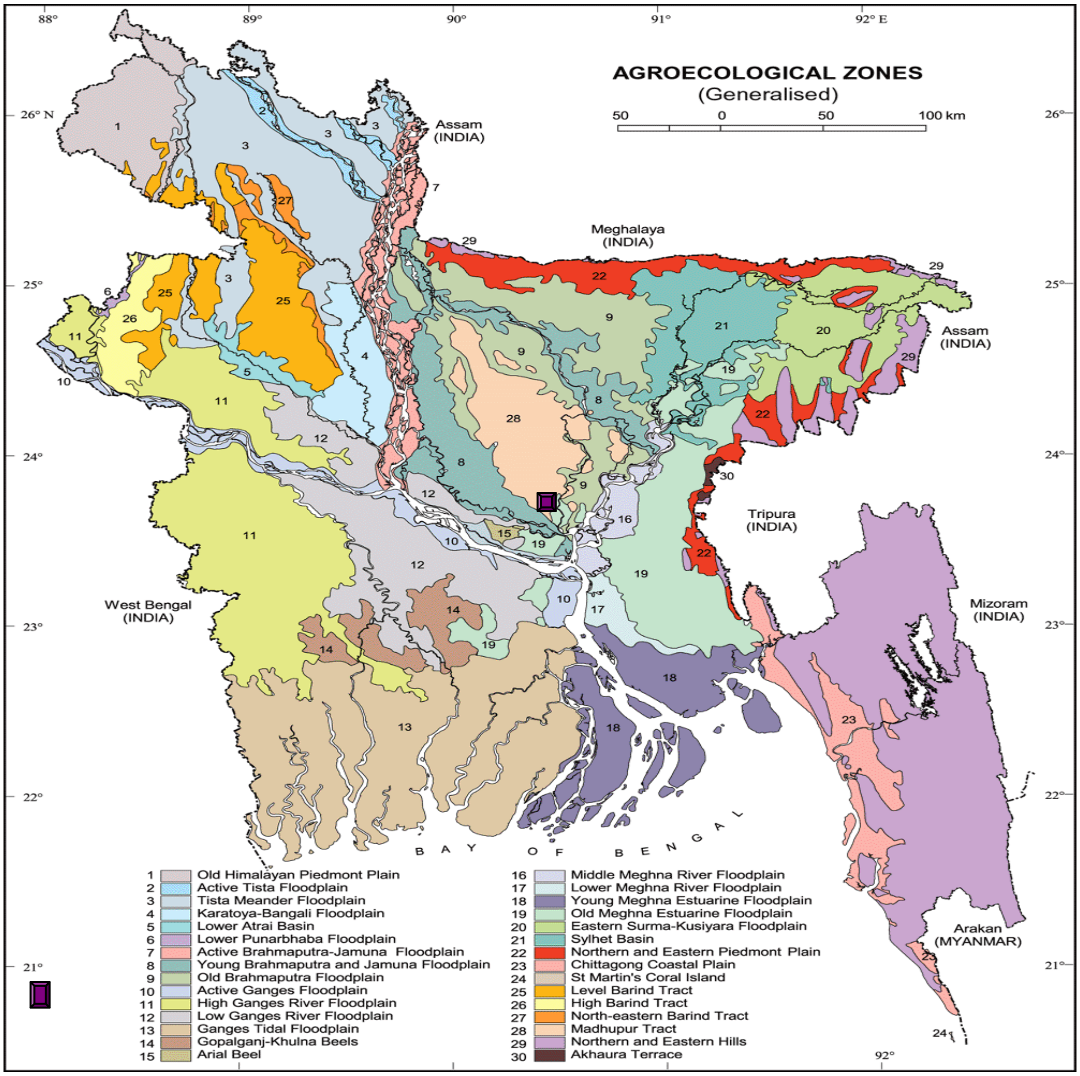
Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Monthly average air temperature, relative humidity and total rainfall of the experimental site during the period from January to July 2010

Month	RH (%)	Max. Temp. (ºC)	Min. Temp. (ºC)	Rain fall (mm)
January	68.58	24.00	14.46	0
February	52.29	29.00	18.48	0
March	47.15	33.00	23.00	0
April	62.43	34.00	24.81	184
May	63.31	36.00	25.95	181
June	65.00	33.50	24.00	186
July	67.00	30.00	23.00	178

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Physiochemical properties of the soil

Sample code	Sample No.	pH	Nitrogen (ppm)	Phosphorus (ppm)	Potassium (ppm)
T_1	1	5.7	0.030	12.63	0.11333
T_2	2	6.133	0.193	11.8	0.12333
T_3	3	6.033	0.036	12.1	0.13333
T_4	4	5.633	0.029	11.93	0.13333
T_5	5	5.866	0.029	12.7333	0.14
T_6	6	5.633	0.029	12.2333	0.13
T_7	7	5.866	0.028	8.00	0.12
T_8	8	5.766	0.041	10.0667	0.12333
T_9	9	5.8	0.039	12.50	0.13333
T_{10}	10	5.9	0.043	23.2467	0.13333
T_{11}	11	6.16	0.0136	11.8333	0.11667
T_{12}	12	5.76	0.033	9.8	0.11667
T_{13}	13	5.43	0.046	12.2	0.16667
T_{14}	14	6.63	0.0256	13.2667	0.17

Source: SRDI, Khamarbari, Farmget, Dhaka.