EFFECT OF MAIZE-LEGUMES INTERCROPPING ON GROWTH AND YIELD OF MAIZE

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CERTIFICATE

This is to certify that the thesis entitled ***"EFFECT OF MAIZE-LEGUMES INTERCROPPING ON GROWTH AND YIELD OF MAIZE"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) in AGRONOMY****, embodies the result of a piece of bona-fide research work carried out by* ***MAHFUZUL KARIM TUSHAR,*** *Registration no.* ***15-06842*** *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 duly been acknowledged.

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Dedicated to

My

Beloved Parents

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The Author

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ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from October-2021 to February-2022 in Rabi season, to study the effect of maize-legumes intercropping on growth and yield of maize. The experiment consisted of single factors, and followed Randomized Complete Block Design (RCBD) with three replications. Four intercropping systems *viz:* T_1 = sole hybrid maize, T_2 = hybrid maize + soybean, T_3 = hybrid maize + grasspea and T_4 = hybrid maize + soybean + grasspea were used in this study. Significant differences in maize growth, yield attributes and yields were found among the various intercropping systems. The highest plant height of maize (223.11 cm), total dry matter plant^{-1} (186.93 g), cob length (16.27 cm), cob diameter (5.03 cm), number of rows cob^{-1} (15.99), number grains cob^{-1} (420.66), grain weight plant^{-1} (109.19 g), 100-grain weight (23.42 g) were observed in T_1 (sole hybrid maize cropping). However, the highest systematic grain yield (9.37 t ha^{-1}), systematic stover yield (17.11 t ha^{-1}) and systematic biological yield (26.48 t ha^{-1}) were observed in T_4 (maize + soybean + grasspea) treatment, while the lowest systematic grain yield (7.97 t ha^{-1}), systematic stover yield (11.77 t ha^{-1}) and systematic biological yield (19.74 t ha^{-1}) were observed in T_1 (sole maize). In terms of economic return, the highest benefit-cost ratio (BCR) was observed in T_4 (maize + soybean + grasspea), while the lowest benefit-cost ratio (BCR) was observed in T_1 (sole hybrid maize cropping). Therefore, the result suggested that maize + soybean + grasspea intercropping system was found to be the best intercropping system for higher grain production.

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LIST OF ABBREVIATIONS

Full word	**Abbreviations**
Agriculture	Agr.
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Biotechnology	Biotechnol.
Botany	Bot.
Centimeter	cm
Cultivar	Cv.
Dry weight	DW
Editors	Eds.
Emulsifiable concentrate	EC
Entomology	Entomol.
Environments	Environ.
Food and Agriculture Organization	FAO
Fresh weight	FW
Gram	g
Hectare	ha
International	Intl.
Journal	J.
Least Significant Difference	LSD
Liter	L
Meter	m
Science	Sci.
Serial	Sl.
Soil Resource Development Institute	SRDI
Technology	Technol.
Ton	t
Triple Super Phosphate	TSP

CHAPTER I

INTRODUCTION

Attaining food and nutritional security for millions of people worldwide is one of the most stressful challenges, particularly for densely populated countries, such as Bangladesh (GFSI, 2022). Weather and climate are prominent drivers or influencers of agricultural production systems and the recent trends in change of climate variables may be responsible for substantially affecting crop yield (Kukal and Irmak, 2018). Bangladesh, the world's largest delta, is a riverine country that is highly susceptible to climate and weather-related and geophysical hazards due to its topography and geographical location (ADB, 2021). Crop diversification can improve soil fertility and water-use efficiency, and maintain natural enemies of insect pests, while a monoculture system with a single species (rice as in case of Bangladesh) often accelerates nutrient mining from a particular soil layer and hosts pathogenic microorganisms. Moreover, a diversified cropping system is not only a resilient and sustainable crop production technique (Mango *et al*., 2018) but it also provides large varieties of food with different nutritional qualities (Steward *et al*., 2019).

Intercropping is a well-known practice of diversified cropping systems and therefore, it could provide similar benefits. For instance, it can efficiently use growth resources, including nutrients, light, and water, thus maintaining soil health (Martin-Guay *et al*., 2018). Moreover, the chances of getting yield from at least one of the component crops, even under adverse climatic conditions (e.g., cyclones), is higher than monocropping. Therefore, it has been reported that intercropping could provide a stable yield from the component species (Rahman *et al*., 2021). However, competition between component crops for resources can significantly reduce yield. Thus, it is an important determinant for selecting component crops in intercropping systems since species diversity can reduce resource competition (Brooker *et al*., 2016). For instance, intercropping is more productive and economical when both crops differ in genetic makeup, photosynthetic pathways, growth habit, growth duration, and demand for different growth resources (Tilman, 2020). Therefore, intercropping can only provide a yield advantage over sole cropping if the component crops use natural resources in complementary ways (Brooker *et al*., 2015).

Cereal–legume intercropping is an important agronomic practice in which the system's efficiency is superior to the individually grown component species (Zhang *et al*., 2020). For instance, maize (*Zea mays*)–legume intercropping has multiple benefits over sole cropping and intercropping practices than other species (Renwick *et al*., 2020). These benefits may have been achieved through symbiotic associations and complementary interactions between species in harvesting limited resources (Rahman *et al*., 2021). When maize is planted as a wide-spaced crop, it encourages weed infestation and intensifies crop–weed competition (La Guardia Nave and Corbin, 2018); meanwhile, there remain unexplored opportunities of getting a harvest from the free space. Growing a component crop in between lines of maize can substantially reduce weed growth. The benefits can be even greater when a legume is selected as a component crop since it can supplement some of its fixed nitrogen to other component crops (Rodriguez *et al*., 2020). Moreover, maize and legumes may uptake nutrient elements and water from different layers since their root architecture and penetration depth are different (relatively shallow vs. deep in maize and legume, respectively). Thus, there is less competition between species (Jensen *et al*., 2020).

Maize can be potential cereals for multiple reasons since it provides several outputs, including food and fodder. The demand of maize in Bangladesh is increasing since it is used in animal feed as well as in different food items. In 2018, the demand was 4.48 million tons while the production was 3.28 million tons from ~400-thousand-hectare lands (Jiang *et al.*, 2021). On the other hand, soybean (*Glycine max* L) is an annual grain legume known for its high protein content, vitamins, and minerals (Mirriam *et al*., 2022). It is a restorative plant that improves the quality and health of the soil by enriching it with nutrients (Zaeem *et al*., 2019). While grasspea (*Lathyrus sativus* L.), is a high yielding and important annual food and feed legume, cultivated mainly in Asia and Africa (Larbi *et al*., 2011). The forage and grain of grasspea is an important source of protein for livestock animals such as poultry, sheep and pigs (Winiarska-Mieczan, 2010). The content of essential amino acids, proteins and carotene in grasspea forage is higher than other legumes (Sidorova *et al*., 2013). The plant is recommendable for agricultural systems due to the ability for biological nitrogen fixation, resistance to drought and high fodder nutritional value (Larbi *et al*., 2011).

Considering the diversity of each species, there can be positive interactions when maize and legumes are grown together. For instance, Dong *et al*. (2018) reported a relative advantage of maize–legume intercropping over sole cropping and intercropping of maize with other species due to interspecific facilitation by processes of N_2 fixation, N transfer, and increased resource availability. However, there can still be significant competition for resources when component species are grown simultaneously (Li *et al*., 2014). There are several potential means to reduce competition, including (a) reducing the plant population density (widely sown maize and legume plants), (b) creating a difference in resource demand (sowing maize and legume at different times), and (c) managing the optimum growing conditions through agronomic practices (e.g., canopy pruning of dominant species) (Yu *et al*., 2015). Thus, intercropping maize with soybean and grasspea not only secures the regional food demand and nutritional quality of the forage industry but also improves the nutrient status of the maize crop besides providing an environmentally friendly and promising agricultural system for the future development.

In Bangladesh few studies have been conducted with maize-legumes intercropping on grain yield and yield components of maize. Research work on the effect of maize-legumes intercropping is limited. Considering the above facts the present study was undertaken to find out the effect of maize-legumes intercropping on growth and yield of maize with the following objectives:

i. To explore the effects of different maize-legumes intercropping systems on growth and yield of maize.
ii. To determine the best intercropping system for increasing maize yield.
iii. To find out the economic feasibility of different maize-legumes intercropping systems.

CHAPTER II

REVIEW OF LITERATURE

Intercropping, an important feature of crop production, is mostly considered as an insurance against vagaries of weather or natural calamities. Recently intercropping has been recognized as a potentially beneficial system of crop production and research evidence also suggests that intercropping can provides substantial yield advantages compared to sole cropping by simple expedient of growing crops together. There is ample scope of maize cultivation in Bangladesh, but to explore its possibility there is a need to work out the agronomy of maize, especially hybrid maize intercropping system. Relevant review of literature pertaining to the effect of maize-legumes intercropping on growth and yield of maize is reviewed in this chapter under the following headings. The literature on maize with field soybean and grasspea intercropping system is meagre and hence related reviews are included in this chapter.

2.1 Intercropping systems

Andrews and Kassam (1976) stated that intercropping is an age-old practice of growing simultaneously two or more crops in the same piece of land. It is a technique of crop intensification in both time and space wherein the competition between crops may occur during a part or whole of crop growth period. It has been a common practice followed by the farmers of India, Africa, Sri Lanka, West Indies and Bangladesh.

Lakhani (1976) and Sivakumar and Virmani (1980) reported that higher yield in terms of total biomass and grain production per unit area in a given season without the use of costly inputs under intercropping system is attributed to better use of growth resources namely, light, moisture and nutrients.

Willey and Rao (1980) stated that the crop mixtures would also stabilize returns over seasons as they provide more than one commodity and can act as buffer against frequent price changes in any one of the component crops.

Tsubo and Walker (2002) measured photosynthetically active radiation above and beneath a maize-bean intercrop canopy in both north-south and east-west rows. They observed that the intercropping was equivalent in growth efficiency of maize to the sole cropping whereas, beans had greater radiation use efficiency in intercropping than in sole cropping. This might explain the intercrop yield advantage.

2.2 Advantages of intercropping

The main advantage of intercropping is the more efficient utilization of the available resources and the increased productivity compared with each sole crop of the mixture (Hauggaard and Jensen, 2001). Intercropping is one way of introducing more biodiversity into agro ecosystems and results from intercropping studies indicate that increased crop diversity may increase the number of ecosystem services provided. Higher species richness may be associated with nutrient cycling characteristics that often can regulate soil fertility (Russell, 2002), limit nutrient leaching losses (Hauggaard *et al.*, 2003), and significantly reduce the negative impacts of pests also including that of weeds. Barik *et al.* (1998) reported that the intercropping serves as an insurance against total crop failure in uncertain weather condition, increasing total productivity, equitable and judicial use of land resources and farming inputs including labour. Assefa and Ledin (2001) revealed that the intercropping can provide better lodging resistance for some crops highly susceptible to lodging. Kariaga (2004) found that intercropping controls soil erosion by preventing rain drops from hitting the bare soil where they tend to seal surface pores, prevent water from entering the soil and increase surface erosion. In maize-legumes intercropping, legume acts as the best cover crop and reduces soil erosion. Mashingaidze (2004) found that by intercropping land was effectively utilized and yield was improved. Reddy and Reddi (2007) mentioned that taller crops act as wind barrier for short crops.

2.3 Maize-legume intercropping

Jamshidi (2013) revealed that increasing the maize density from 7.5 to 9 plants m^{-2} reduced the weed biomass by 21.5%. Furthermore, cowpea acted as living mulch, reducing weed biomass by up to 45.5% and 39.6% when intercropped with maize at a density of 7.5 and 9 plants m^{-2}, respectively. Under weed-free conditions, an increase in maize density from 7.5 to 9 plants m^{-2} resulted in maize grain yield increasing from 8.92 to 9.40 t ha^{-1}; however, the addition of cowpea only increased the maize grain yield by about 4.2%, on average, under these conditions. By contrast, under weed-infested conditions, there was a large decrease in maize grain yield (up to 32%), but intercropping with cowpea reduced this to only a 16% decrease. Bilalis *et al.* (2010) reported that intercropping maize with legumes considerably reduced weed density in the intercrop compared with maize pure stand due to decrease in the available light for weeds in the maize-legume intercrops, which led to a reduction of weed density and weed dry matter as compare to the sole crops. Mongi *et al.* (1976) revealed that maize-cowpea intercropping suppresses weeds and insures against total crop failure when one crop fails.

Dahmardeh *et al.* (2010) observed that maize-cowpea intercropping increases the amount of nitrogen, phosphorous and potassium contents compared to mono crop of maize. Ghanbari *et al*. (2010) reported that intercropping maize with cowpea has been increase light interception in the intercrops, reduce water evaporation, and improve conservation of the soil moisture compared with maize alone. Ghosh (2007) observed that among legume-cereal intercropping system, the combination of maize + pigeonpea was considered to be highly suitable with a minimum competition for nutrients, while legume + legume intercropping system, pigeonpea + groundnut system was the most efficient one in terms of resource use efficiency. Tsubo *et al.* (2003) found that the maize-legume intercropping systems are able to lessen amount of nutrients taken from the soil in comparison to a maize monocrops.

Hugar and Palled (2008) found that the maize-french bean intercropping gave high maize equivalent yield over sole maize yield. Tsubo *et al.* (2002) observed the higher crop productivity and resource use efficiency in maize-bean intercropping systems than respective sole cropping. Pal and Shehu (2001) found that all legume crops contributed to yield and N uptake of maize either intercropped with legume or grown after legume as a sole crop. West and Griffith (1992) observed that the yield of maize was increased by 26% in maize-soybean strip intercropping.

2.4 Effect of intercropping on growth and yield of maize

Biruk *et al*. (2021) carried out an experiment during the 2017-18 cropping season at Kako, Bena Ttsemay woreda, South Omo zone, Southern Ethiopia to determine the effect of intercropping of maize and cowpea on the yield, land use efficiency and profitability of both crops. The experiment consisted of 4 treatments (sole maize, sole cowpea, one row of maize to one row of cowpea and one row of maize to two rows of cowpea) and laid in RCBD in four replications. Intercropping of one row of maize to one row of cowpea and one row of maize to two rows of cowpea, resulted in 55.8% and 27.9% greater land use efficiency than for either crop grown alone. The highest monetary advantage index (MAI) was obtained by growing one row of maize to one row of cowpea (11563.17) followed by one row of maize to two rows of cowpea (6783.50).

Cheng-Dong *et al*. (2019) conducted a field experiment to compare the suitability of different maize varieties in intercropping. In the farm study, the grain yield of maize intercropped with watermelon was reduced by more than one third as compared to maize in wheat-maize double cropping, mainly due to lower ear density and lower 100-grain weight. Under real farm conditions, the yield of intercropped maize increased with increasing ear density and 100-grain weight, while yield of sole maize increased with increasing grain number per ear and 100-grain weight. In the field experiments, the maize cultivars commonly used in double cropping gave similar yields when grown in the intercropping system and their yields were closely related to ear density and 100-grain weight.

Khan *et al.* (2018) conducted an experiment at the farmers' field of Phulpur MLT site of On-Farm Research Division, Bangladesh Agricultural Research Institute (BARI), Mymensingh during 2015-16 and 2016-17 to find out a suitable intercrop combination of garden pea with maize for higher productivity and profitability with the following treatments, T_1= Maize (100%) + one row garden pea (33%) in between maize lines, T_2= Maize (100%) + two row garden pea (66%) in between maize lines, T_3= Maize (100%) + garden pea broadcast (100%) in between maize lines, T_4= Sole maize and T_5= Sole garden pea were tested following RCB design with six dispersed replications. The result stated that intercropping of garden pea improved the yield components of maize and offered some additional yield. The highest maize grain yield (8.62 t ha^{-1}) and maize equivalent yield (20.22 t ha^{-1} yr^{-1}) were recorded with maize (100%) + two rows of garden pea (66%) in between maize lines (T_2).

Nwite *et al.* (2017) reported that the groundnut and maize intercrop had 33, 4 and 44% higher grain yield of maize compared to values recorded in plots receiving soybean and maize as well as bambaranut and maize intercrop and sole maize. Ashish *et al.* (2015) reported that the maize grain, stover and biological yield under maize + mashbean intercropping system were 4.0, 2.5 and 3.0% respectively higher as compared to sole planting.

Hamdalla *et al.* (2014) carried out a field experiment at Arab El Awammer Research Station, Agric. Res. Center. Assiut Governorate during summer seasons of 2013 and 2014. The present study assessed the effect of cowpea with maize intercropping on yield and its components. The experiment comprised of three treatments (sole cowpea, sole maize and cowpea-maize intercrop). The experimental design was a randomized complete block with four replications. Results indicated that intercropped maize plants with cowpea, exhibited greater potentiality and resulted in higher values of most of the studied criteria viz., plant height, number of ears plant^{-1}, number of rows ear^{-1}, number of grains row^{-1}, grains weight ear^{-1}, 100–grain weight and straw and grain yields. Fresh and dry forage yields of cowpea were lower in intercropping with maize than sole. Furthermore, the combined of the two seasons revealed that the total Land Equivalent Ratio (LER) between cowpea and maize was 1.65. The Aggressivity (A) of maize was 0.45 and cowpea was -0.45. This showed that maize was the dominant crop, whereas cowpea was the dominated. The Competitive Ratio (CR) indicated that maize (1.75) was more competitive than cowpea (0.57). The Actual Yield Loss (AYL) of maize was 0.05 and cowpea was -0.40. The Monetary Advantage Index (MAI) was 2360.80.

Khatri *et al.* (2014) conducted a field experiment was at National Maize Research Program (NMRP) in Rampur, Chitwan, Nepal during May-Nov 2013. The experiment was laid out in strip-split design with twelve treatments and three replications. Treatments consisted of two different tillage methods namely conventional tillage (CT) and zero tillage (ZT) as vertical factor, two different levels of residue (residue kept and residue removed) as horizontal factor and three different levels of cropping systems namely sole maize, sole soybean and maize + soybean intercropping system as sub plot factor. Manakamana-3 and Puja were the variety of maize and soybean used for the experiment respectively. The results revealed that the grain yield and yield attributing components of maize and soybean was significantly influenced by cropping systems but not by tillage methods and residue levels. The grain yield of maize obtained under sole cropping (4.76 t ha^{-1}) was significantly higher than maize + soybean intercropping system (4.27 t ha^{-1}). Similarly, the grain yield of sole soybean cropping was significantly higher (1.99 t ha^{-1}) than that of maize + soybean intercropping system (1.26 t ha^{-1}). Moreover, the total grain yield equivalent of 6.45 t ha^{-1} obtained from sole soybean system was significantly higher and was followed by maize and soybean intercropping system with 4.99 t ha^{-1}, whereas, sole maize produced significantly the lowest maize grain yield equivalent of 3.47 t ha^{-1}. Significantly, higher LER (1.38) was recorded with maize and soybean intercropping system over sole system (1.0). Tillage and residue levels did not affect the gross and net return and B:C ratio but the effect was found obvious due to intercropping system. Significantly higher net return was recorded in intercropping of maize with soybean as compared to sole soybean which was at par with sole maize system. Maize and soybean intercropping system produced significantly the higher (2.47) B:C ratio than sole soybean (2.28) and was at par with sole maize (2.18).

Mandal *et al.* (2014) observed that the grain yield and stover yield of maize were significantly higher in case of pure stand of maize than either of its intercropping systems with legumes while the cob yield was highest in the maize with soybean (1:2) intercropping system and it was statistically at par with the yield obtained in sole maize. The grain yield of legume was highest in maize with groundnut intercropping (1:2) and it had the highest yield followed by sole groundnut. The maize equivalent yield was highest in maize with soybean intercropping (1:2) followed by maize with groundnut (1:2), maize with groundnut (2:4) and maize with soybean (2:4) intercropping. Thus, under the red and lateritic soil condition where cultivation is practiced with limited water, legume crops like groundnut can be grown as intercrops with maize to get higher monetary returns.

Nyasasi and Kisetu (2014) carried out a study to assess the response of maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L. Walp) under sole and intercropping systems. It also determined potential of intercropping system with respect to the proportion of land used for cultivation and the area of land saved. Results indicated that the above-ground total biological yield in sole maize (31.8 t ha^{-1}) was insignificantly ($p = 0.055$) larger than in maize (26.7 t ha^{-1}) intercropped with cowpea. The yield in sole maize (6.53 t ha^{-1}) was significantly (p = 0.003) higher than in maize (6.47 t ha^{-1}) intercropped with cowpea. The mean number of pods per plant in sole cowpea (7.7) was significantly (p = 0.039) higher than in cowpea (6.8) intercropped with maize. In addition, the mean number of seeds per pod in cowpea intercropped with maize (15.0) was significantly (p = 0.009) lower than in sole cowpea (15.43). Furthermore, cowpea seed yield in sole cowpea (6.7 t ha^{-1}) was significantly (p = 0.022) higher than in intercrop (6.25 t ha^{-1}). Further to that, the land equivalent coefficient between maize and cowpea was 0.92 and the competitive ratio between the two crops when intercropped was 1.07. The land saved when the two crops were intercropped was 47.9%.

Sonam *et al*. (2014) conducted a field experiment during kharif season 2011 under "All India Co-ordinated Research Project on Forage Crop" at Farm of Agriculture College, Jabalpur to evaluate "different maize based intercropping system for productivity and economics". The intercropping of maize with soybean, ricebean and cowpea with 1:1 and 1:2 ratios gave higher maize equivalent yield than sole crop. The intercropping of maize with soybean 1:2 ratio possessed the maximum energy interception, energy utilization, PAR interception, PAR utilization and also gave the higher LER 1.57 than other treatments. The intercropping of maize with soybean 1:2 ratio was more remunerative and gave maximum yield, net return and B:C ratio.

Dhar *et al.* (2013) reported that in maize + pea intercropping system the 1M:2P combined maize and pea mixture produced maximum seed yield (7.82 t ha^{-1}) which was about 10, 28 and 47% higher yield than the yield obtained from 1M:1P combined mixture stands (7.04 t ha^{-1}), sole maize (5.65 t ha^{-1}) and sole pea (4.15 t ha^{-1}), respectively.

Lemlem (2013) found that intercropping maize with cowpea reduced maize plant height as determined by environmental factors and competition between the two crops. Legwiala *et al.* (2012) observed that only maize dry matter was significantly reduced by intercropping. Intercropping reduced the numbers of cowpea flower per plant weight of seeds. Cowpea dry matter weight was significantly reduced by intercropping. Planting pattern significantly affected the number of cowpea flower, number of pods and dry matter weight.

Undie *et al.* (2012) reported that intercropping maize with soybean in one growing season had no significant effect on grain yield of maize but maize grain and soybean yields were reduced by 6% and 32%, respectively, compared to sole cropping.

In a study conducted by Popescu and Roman (2008), maize was sown at 70 cm between rows and 28.6 cm between plants at a density of 5 plants m^{-2}. Soybean was sown in alternate rows at a density of 24 plants m^{-2}. Maize recorded a vegetation period of 134 days, plant height of 182 cm, and 17 leaves per plant under monoculture (the same vegetation period of 134 days, plant height of 72cm and 16 leaves per plant under intercropping with soybean). Soybean from monoculture registered a vegetation period of 130 days, plant height of 80 cm, and 16 knots per plants (135 days, 87.5 cm height and 14 knots per plant for intercropped soybean). Ahmad *et al.* (2007) observed the maximum plant height, more number of leaves/plant in case of sole crop of forage sorghum as compared to intercropping treatments and concluded that this might be due to more penetration of light, circulation of air, and comparatively more nutritional area available to sole crop under competition free environment.

Dutta and Bandopadhyay (2006) reported that in the intercropping system of groundnut with pigeonpea and maize the yield components were reduced with intercropping than their respective sole crops. Padhi and Panigrahi (2006) reported that maize + blackgram and maize + soyabean at 1:1 row ratio and maize + groundnut at 2:2 row ratio recorded significantly higher total maize grain equivalent yield than respective sole component crops. Singh *et al.* (2004) reviewed that sole maize was significantly superior to maize + cow pea and maize + okra intercropping treatments in respect to green cob and stover yield. However, highest value of maize equivalent yield were associated with maize + cow pea which were significantly superior to maize + okra and sole maize. Randhawa *et al.* (2005) studied maize-legume intercropping to see effect of legume on maize productivity grown in different geometrical patterns. The treatments comprised of: Sole maize, maize + blackgram, maize + mungbean and maize + cowpea at different planting patterns, i.e. P_1 = 90 cm apart double row strips (80/90 cm) and P_2 = 120 cm apart triple row strips (80/120 cm). Maize grain yield was significantly greater in sole maize compared to other treatment combinations; while maize + cowpea intercropping gave minimum yield. Maize grown under P_1 provided the maximum yield of 39.38 q ha^{-1}.

In a study conducted by Selvi *et al.* (2004), it was found that maize + cowpea intercropping system gave significantly higher grain and straw yield of both crops and available N content in soil with 100% NPK + 101 FYM over 100% NPK alone. Hussain *et al.* (2003) reported that maize plant height was reduced by the use of different legumes in an intercropping system. Morgado and Willey (2003) reported that dry matter yield accumulation in an individual maize plant decreased with increase in bean plant population when grown under intercrop. An experiment was laid out by Pandey *et al.* (2003) to study the effect of maize *(Zea mays* L.)-based intercropping systems on maize yield and associated weeds under rainfed condition. Intercropping systems reduced the values of yield attributes and grain yield of maize than sole cropping of maize, but significant reduction in cob length, kernels row^{-1}, grains cob^{-1} and grain yield was recorded only with sesame *(Sesamum indicum* L.), turmeric *(Curcuma longa* L.) and forage meth *[Phaseolus aconitifolius* (jacq) Marechal] intercropping system.

Purushotham *et al.* (2003) conducted a field experiment to find out the effect of seed rate and fertility levels in sole and mixed cropping of fodder maize and cowpea and reported that the growth parameters like plant height, number of green leaves $plant^{-1}$ of sole crop of maize did not differ with mixed cropping. A study conducted by Silwana and Lucas (2002) found that sole maize plant was taller than maize which was intercropped with beans.

Shivay *et al.* (2001) revealed that intercropping of maize with urd bean significantly increased the grain yield of maize compared to sole maize grown both in normal row planting and paired row planting.

Ramanakumar and Bhanumurthy (2001) observed the minimum dry matter content with intercropping system of maize and cowpea during kharif and summer seasons on sandy loam soils of Ranjendranagar (Andhra Pradesh). Jha *et al.* (2000) reported the highest plant height, leaf area index and dry matter accumulation in maize when grown sole as compared to intercrop with different potato varieties.

Moses *et al.* (2000) conducted a field experiment to explore the potential of intercrop pulses by manipulating the spatial configuration of maize hybrid DHM-103 from uniform 60 to 40-80 cm paired rows. The results showed that two rows of green gram, black gram or one row of pigeonpea can be intercropped between paired rows of maize. The adequate fertilizer dose was to apply 80, 40 and 20 kg ha^{-1} N, P_2O_5 and K_2O to maize and 50% or entire recommended dose of 20, 50 and 20 kg ha^{-1} NPK to the intercrops. Maize yield components viz., cob length, grains cob^{-1} and 100-grain weight were not critically reduced with no interrupted uptake of N, P and K and thus yielding as much grain or stover as in sole maize. Pattanashetti (2000) reported that sole crop of both maize and soybean recorded significantly higher grain yield (6,475 and 1,259 kg ha^{-1} respectively) as compared to their respective intercrops. However, intercropping of maize and soybean produced significantly higher maize equivalent yield (6,976 kg ha^{-1}) as compared to sole crop of maize.

CHAPTER III

MATERIALS AND METHODS

This part presents a concise depiction about the duration of the experimental period, site description, climatic state of the area, harvest or planting materials that are being utilized in the test, treatments, design, crop growing procedure, intercultural activities, data collection and statistical analyses.

3.1 Experimental period

The experiment was conducted during the period from October, 2021 to February, 2022 in Rabi season.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Agargaon, Dhaka, Bangladesh. The experimental site is topographically situated at 23°77′ N scope and 90°33′ E longitude at an elevation of 8.6 meter above sea level.

3.2.2 Agro-Ecological Zone

The experimental field belongs to the Agro-ecological zone (AEZ) of “The Modhupur Tract”, AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain. For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I (Banglapedia, 2014).

3.3 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Biswas *et al.*, 2019). Meteorological data related to the temperature, relative humidity and rainfall during the experiment period of was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-II.

3.4 Soil

The soil of the experimental pots belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 5.4–5.6. The land was above flood level and sufficient sunshine was available during the experimental period. The morphological, physical and chemical characteristics of the experimental soil have been presented in Appendix-III (Biswas *et al*., 2019).

3.5 Planting materials

In this research work, seeds of hybrid maize *viz*; BARI Hybrid Maize-7, BARI Soybean-6 and BARI Khesari-4 were used as planting material. The seeds were obtained from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701.

3.6 Treatment of the experiment

The treatment consisted of single factor having four crop configurations which are given below:

T_1 = Sole hybrid maize
T_2 = Hybrid maize + soybean
T_3 = Hybrid maize + grasspea and
T_4 = Hybrid maize + soybean + grasspea

3.7 Experimental design

The experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. The field was divided into 3 blocks to represent 3 replications. Total 12 unit plots were made for the experiment with 4 treatments. The size of each unit plot was 8.75 m^2 (3.5 m × 2.5 m). Distance maintained between replications and plots were 0.5 m and 0.25 m, respectively. Layout of the experimental field was presented in Appendix-IV.

3.8 Detail of experimental preparation

3.8.1 Preparation of experimental land

The land was opened with the help of a tractor drawn disc harrow on (19 October 2021) and then ploughed with rotary plough twice followed by laddering to achieve a medium tilth required for the crop under consideration. All weeds and other plant residues of previous crop were removed from the field. Immediately after final land preparation, the field layout was made on (19 October 2021) according to experimental specification. Individual plots were cleaned and finally the plots were prepared.

3.8.2 Seed treatment

In order to prevent the crop from seed and soil borne diseases, the seeds were treated with Carbendazim @ 3 g kg^{-1} of seed followed by *Rhizobium* culture @ 5 g kg^{-1} of seed. Then treated seeds were dried in shade for 3-4 hours before sowing.

3.8.3 Fertilizer application

Recommended dose of fertilizer *i.e*. 150:75:40 kg ha^{-1} N, P, and K through urea, Single Super Phosphate (SSP) and Muriate of Potash (MoP) for maize and 25:60:30 kg ha^{-1} N, P, and K through urea, SSP and MoP for soybean and grasspea were applied. In soybean and grasspea full dose of N, P and K was given at the time of sowing, whereas in maize, 1/3rd nitrogen, full P and K was applied at the time of sowing. Top dressing of 1/3rd N was done at knee height stage and remaining 1/3rd was applied at the time of tasseling.

3.8.4 Seed sowing and maintaining spacing

The maize seeds were sown in lines according with par treatment requirement, having 2 seeds $hole^{-1}$ under direct sowing in the well prepared plot on 20 October 2021.

3.9 Intercultural operations

After raising seedlings, various intercultural operations such as irrigation, weeding, gap filling and thinning, drainage, pest and disease control etc. were accomplished for better growth and development of the maize seedlings.

3.9.1 Gap filling and thinning

Gap filling was done at seventh day after sowing to maintain uniform plant population. Thinning was done two weeks after the sowing in order to maintain required plant density in each plot. By pulling out the excess seedlings in each spot, one seedling retained at each spot to maintain optimum plant population per plot.

3.9.2 Weed management

In intercropping system Intercropping suppresses weeds better than sole cropping and provides an opportunity to utilize crop themselves so weeds were managed by one manual hand weeding at 25 days after sowing (DAS).

3.9.3 Water management

Protective irrigation was provided to the crop depending upon the soil moisture content and prevailing weather conditions during the period of experiment. Five irrigations were given for the entire crop growth to avoid moisture stress.

3.9.4 Earthing up

Earthing up was done at 30 DAS along with second hand weeding and top dressed with urea for maize. It helped to give the better anchorage and favorable environment for root growth and development. It also helped to loosen the soil, to reduce the bulk density and to increase the water holding capacity of the soil**.**

3.10 Plant protection measure

Plant protection measures were adopted as and when needed during crop growth period. Quinolphos @ 1.0 liters ha^{-1} was applied at 30 DAS to reduce the infestation of leaf defoliator insects.

3.11 Harvesting

Harvesting was done manually from net plot area when the seed became hard and leaves turned yellow in colour in soybean and grasspea and harvest maize crop when husk has turned yellow and grains are hard enough having less than 30% moisture. The plants were left in plot for five days to sun dry and thereafter bundles were made and the bundle weight $plot^{-1}$ was recorded.

3.12 Threshing and winnowing

Threshing of produce of each net plot was done manually by beating with wooden stick in soybean and grasspea and in maize grains are removed by maize shellers. After manual winnowing grain yield $plot^{-1}$ was noted. Stover yield was worked out after subtracting the grain yield from bundle weight.

3.13 Studies on crop

For study of effect of hybrid maize + soybean + grasspea intercropping with different crop configuration on productivity and economics of hybrid maize based intercropping system, several observations were recorded on the growth parameters and yield attributing characters of crop. For recording pre-harvest and post-harvest observations, five plants were randomly selected from each plot and tagged.

3.14 Collection of different data

Data were collected on the following parameters:

i. Plant height (cm)
ii. Total dry matter $plant^{-1}$ (g) at harvest
iii. Cob length (cm)
iv. Cob diameter (cm)
v. Number of rows cob^{-1}
vi. Number of grains cob^{-1}
vii. Grain weight $plant^{-1}$
viii. 100-grain weight
ix. Grain yield (t ha^{-1})
x. Stover yield (t ha^{-1})
xi. Biological (t ha^{-1})
xii. Harvest index (%)

3.15 Procedure of recording data

A brief outline on data recording procedure followed during the study is given below.

i. Plant height (cm)

At harvest the height of five randomly selected plants from the inner rows plot^{-1} was measured from ground level to the tip of the plant portion and the mean value of plant height was recorded in cm.

ii. Total dry matter plant^{-1} (g) at harvest

At harvest 5 plants from each plot were uprooted randomly. Then the plant was cut into pieces. Then the various pieces of the plant were put into a paper packet, in case of harvesting, cob was also put into a packet and placed in oven maintaining 70°C for 72 hours. Then the sample was transferred into desiccators and allowed to cool down at room temperature. Then the sample weight was taken and then the total dry matter of a plant was calculated for each plot. It was performed at harvest.

iii. Cob length (cm)

Cob length was measured in centimeter. Cob length was measured from the base to the tip of the cob of the five selected plants in each plot with the help of a centimeter scale then average data were recorded.

iv. Cob diameter (cm)

The cob diameter of five cobs from each plot was measured by using verniercaliper at harvesting stage and the means were worked out and expressed in centimeter.

v. Number of rows cob^{-1}

Five cobs from each plot were selected randomly and the number of grain rows per cob was counted. Then the average result was recorded.

vi. Number of grains cob^{-1}

The number of grains per cob was measured from the base to tip of the ear collected from five randomly selected cobs of each plot and finally average result was recorded.

vii. Grain weight plant^{-1} (g)

Total seeds from five plants were randomly selected from each plot and weighed in an electrical balance. In grams, the average grain weight was reported.

viii. 100-grain weight (g)

A random sample of hundred grains was taken from total grain lots of each treatment, weighed and recorded as test weight in grams.

ix. Grain yield (t ha^{-1})

Grain yield of the net plot was noted down, after threshing, winnowing and drying then calculated in kg ha^{-1}with appropriate multiplication factor.

x. Stover yield (t ha^{-1})

After separation of grains from shell, all the parts except grains from harvested area was sun dried and the weight was recorded and then converted into t ha^{-1}.

xi. Biological yield (t ha^{-1})

Grain yield and Stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Grain yield + Stover yield.

xii. Harvest Index (%)

Harvest Index indicates the ratio of economic yield (grain yield) to biological yield and was calculated with the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.16 Statistical data analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program Statistix 10 software. The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability (Gomez and Gomez, 1984).

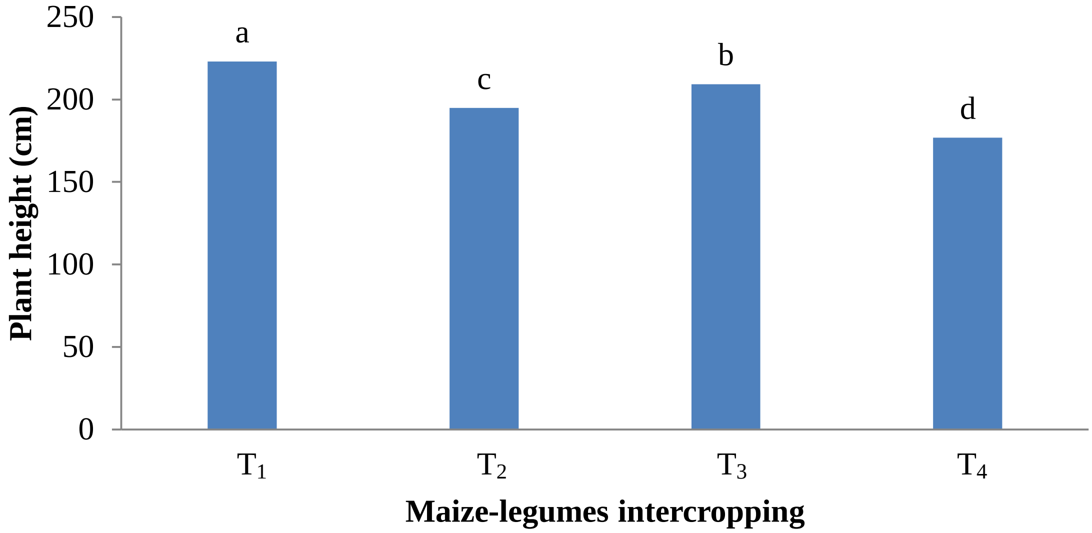
CHAPTER IV

RESULTS AND DISCUSSION

This section contains a presentation and discussion of the study's findings on the effect of maize-legumes intercropping on growth and yield of maize. The information was presented in various tables and figures. The findings had been discussed, and possible interpretations were provided under the headings listed below.

4.1. Plant height (cm)

Plant height is an essential character of the vegetative stage of the crop plant and indirectly impacts yield of crop plants. Different treatments significantly influenced plant height of maize at harvest (Figure 1). The highest plant height of maize (223.11 cm) was observed in T_1 (sole maize), while the lowest plant height (176.78 cm) was observed in T_4 (maize + soybean + grasspea) treatment (Figure 1). The maximum plant height in case of sole crop was attributed to penetration of light, circulation of air and comparatively more nutritional area available to sole crop under competition free environment. While, decrease in plant height in intercropped situation, was ascribed to the fast growth of intercrops at an early growth stage and competition offered by intercrop for different environmental resources which suppressed growth of the companion crop. The current results are in accordance with the findings of Lemlem (2013) who found that intercropping maize with cowpea reduced maize plant height as determined by environmental factors and competition between the two crops. Ahmad *et al.* (2007) observed the maximum plant height, in case of sole crop of forage sorghum as compared to intercropping treatments and concluded that this might be due to more penetration of light, circulation of air, and comparatively more nutritional area available to sole crop under competition free environment. Hussain *et al.* (2003) reported that maize plant height was reduced by the use of different legumes in an intercropping system.

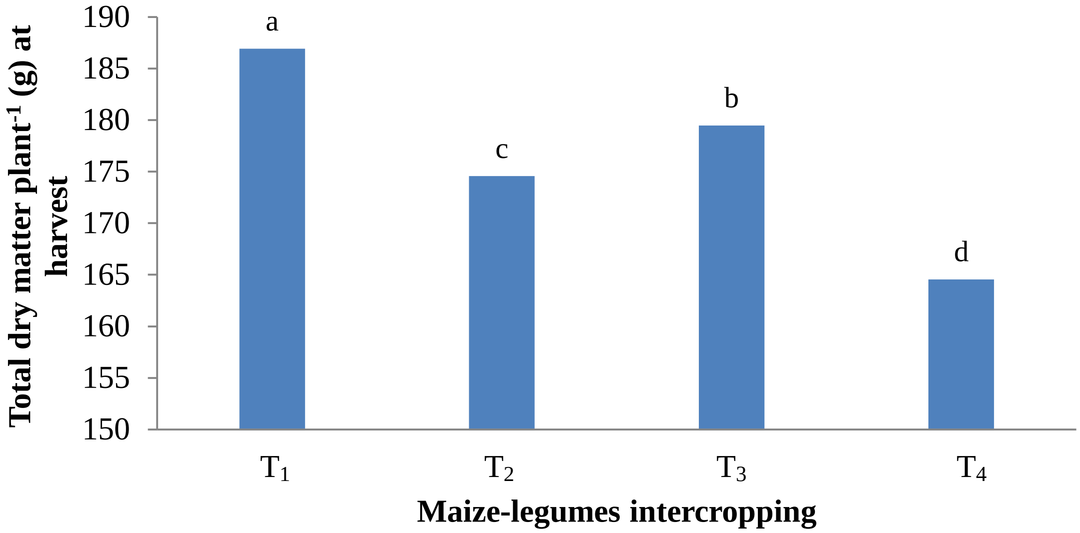


In the bar graph, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, T_1 = sole hybrid maize, T_2 = hybrid maize + soybean, T_3 = hybrid maize + grasspea and T_4 = hybrid maize + soybean + grasspea.

Figure 1. Effect of maize-legumes intercropping on plant height of maize

4.2 Total dry matter plant^{-1} (g) at harvest

At harvest, maize showed significant difference in respect of above ground total dry matter plant^{-1} in different crop configuration of hybrid maize based intercropping system (Figure 2). At harvest, significantly maximum above ground total dry matter plant^{-1} (186.93 g) was recorded under T_1 (sole maize) treatment, while the lowest above ground Total dry matter plant^{-1} (164.56 g) was recorded under T_4 (maize + soybean + grasspea) (Figure 2). The variation of above ground total dry matter plant^{-1} of maize among treatments might be due to adverse effect of excessive crop-intercrop competition which resulted in reduction of nutrient uptake and dry matter accumulation by crop compared to sole cropping. Similar findings were reported by Kumar *et al.* (2006) who observed significant reduction in plant height and dry matter accumulation of winter maize under maize + spinach intercropping system over sole maize. Morgado and Willey (2003) reported that dry matter yield accumulation in an individual maize plant decreased with increase in bean plant population when grown under intercrop.

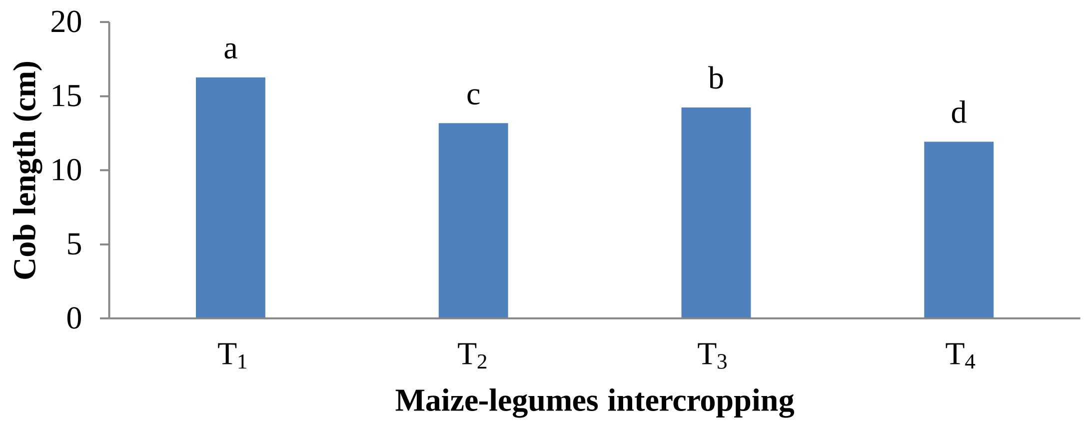


In the bar graph, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, T_1 = sole hybrid maize, T_2 = hybrid maize + soybean, T_3 = hybrid maize + grasspea and T_4 = hybrid maize + soybean + grasspea.

Figure 2. Effect of maize-legumes intercropping on total dry matter plant^{-1} at harvest of maize

4.3 Cob length (cm)

Different maize based intercropping systems significantly influenced cob length of maize at harvest (Figure 3). It was seen from the experimental result that, the highest cob length (16.27 cm) was observed in T_1 treatment, while the lowest cob length (11.93 cm) was observed in T_4 treatment (Figure 3).The variation in maize cob length among different cropping systems may be due to competition for resources such as light, water, and nutrients. When maize plants compete with other plants for these resources, they may not be able to grow well due to lack of proper nutrients and resources result in decreased cob length of maize compared to sole cropping. The result was similar with the findings of Pandey *et al.* (2003) who reported that intercropping systems reduced the values of yield attributes and grain yield of maize than sole cropping of maize.

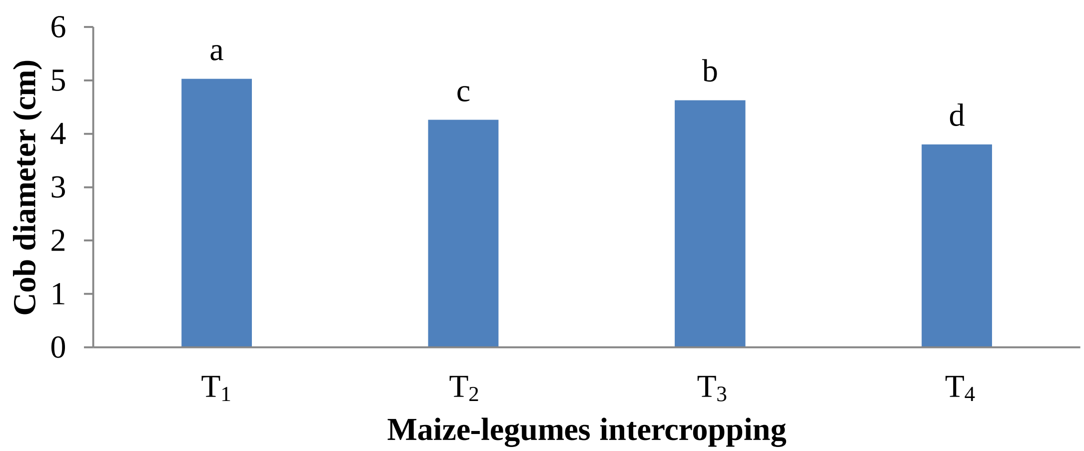


In the bar graph, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, T_1 = sole hybrid maize, T_2 = hybrid maize + soybean, T_3 = hybrid maize + grasspea and T_4 = hybrid maize + soybean + grasspea.

Figure 3. Effect of maize-legumes intercropping on cob length of maize

4.4 Cob diameter (cm)

The cob diameter of maize at harvest was significantly influenced by different maize-based intercropping systems (Figure 4). According to the experimental results, the T_1 treatment had the highest cob diameter of maize (5.03 cm), while the T_4 treatment had the lowest cob diameter of maize (3.8 cm).

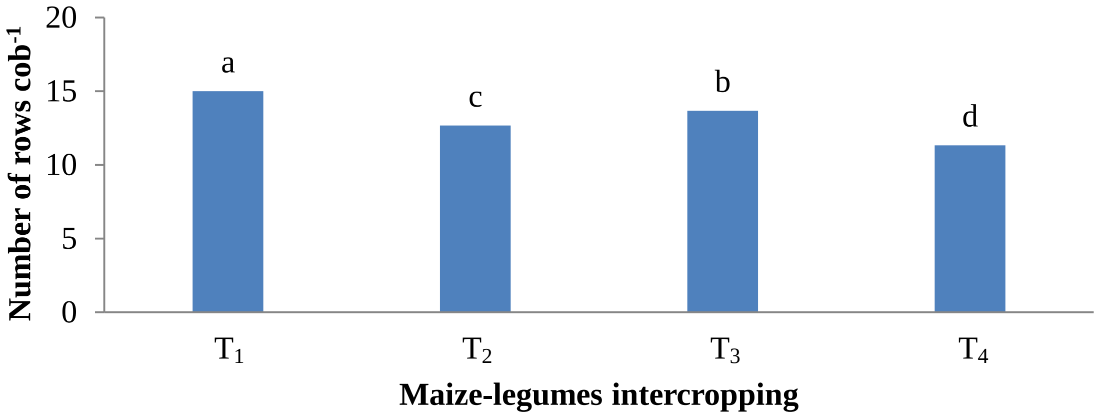


In the bar graph, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, T_1 = sole hybrid maize, T_2 = hybrid maize + soybean, T_3 = hybrid maize + grasspea and T_4 = hybrid maize + soybean + grasspea.

Figure 4. Effect of maize-legumes intercropping on cob diameter of maize

4.5 Number of rows cob^{-1}

The data on number of rows cob^{-1} under various treatments have been presented in Figure 5, which reveal that in maize, T_1 (sole maize) gave significantly higher number of rows cob^{-1} (15.99) however, it was found, the lowest number of grain rows cob^{-1} (11.33) was recorded under treatment of T_4 (maize + soybean + grasspea). The possible reason for lower number of grain rows cob^{-1} in intercropping treatment is due to higher competition of associate crops for light, solar radiation, space, soil moisture and nutrient during entire crop season as compared to the plots of sole crop. Similar findings were reported by Khatri *et al.* (2014) who revealed that the grain yield and yield attributing components of maize was significantly influenced by cropping systems. The number of grain rowscob^{-1} of maize obtained under sole cropping was significantly higher than maize + soybean intercropping system.



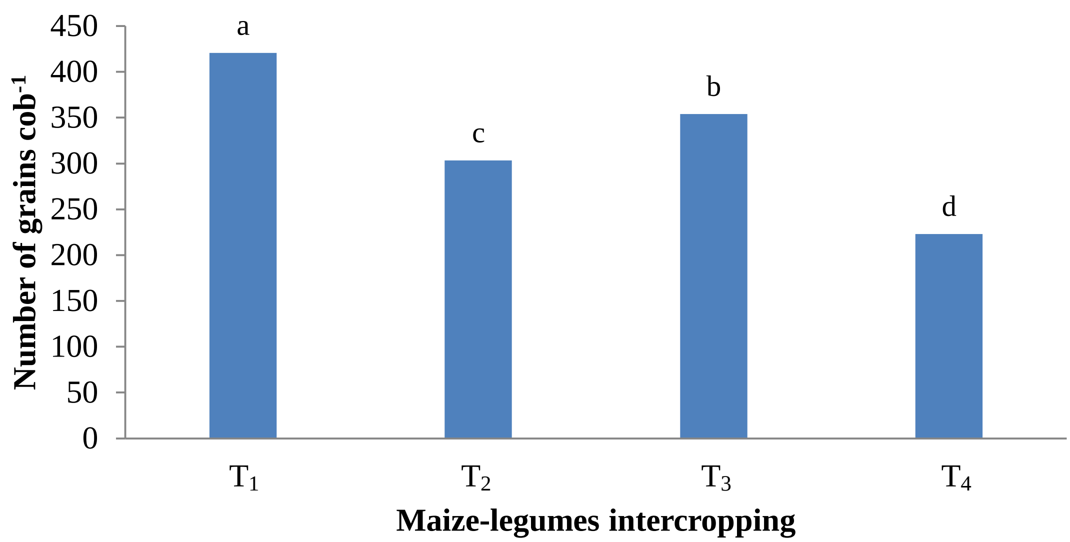
In the bar graph, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, T_1 = sole hybrid maize, T_2 = hybrid maize + soybean, T_3 = hybrid maize + grasspea and T_4 = hybrid maize + soybean + grasspea.

Figure 5. Effect of maize-legumes intercropping on number of rows cob^{-1} of maize

4.6 Number of grains cob^{-1}

The number grains cob^{-1} of maize was significantly varied among different treatments (Figure 6). It was noticed that due to the effect of different treatments the number of grains cob^{-1} ranges from 420.66 to 223.09 (Figure 6). According to the experimental findings, the highest number of grains cob^{-1} of maize (420.66) was observed in T_1 treatment, while the lowest number grains cob^{-1} of maize (223.09) was observed in T_4

treatment. The reduced number of grains cob^{-1} of maize in intercropping system might be due to inter-specific competition for growth resources *viz*., light, moisture and nutrient. The competition existed might be due to increased population pressure per unit land area or demand exceeding supply or both. Better growth of individual plant in low-density populations and resultant utilization of accumulated photosynthates influenced the growth and development of yield attributes of maize as a sole cropping system compared to intercropping system. The result was similar with the findings of Dutta and Bandopadhyay (2006) who reported that in the intercropping system of groundnut with pigeonpea and maize the yield components were reduced with intercropping than their respective sole crops.

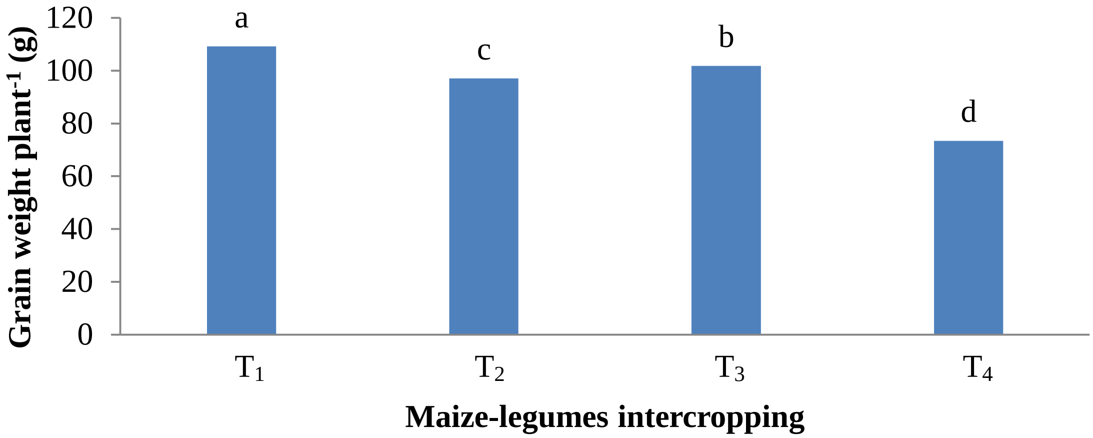


In the bar graph, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, T_1 = sole hybrid maize, T_2 = hybrid maize + soybean, T_3 = hybrid maize + grasspea and T_4 = hybrid maize + soybean + grasspea.

Figure 6. Effect of maize-legumes intercropping on number of grains cob^{-1} of maize

4.7 Grain weight plant^{-1} (g)

Different intercropping systems had shown significant effect on grain weight plant^{-1} of maize (Figure 7). The experimental result revealed that the highest grain weight plant^{-1} of maize (109.19 g) was observed in T_1 treatment, while the lowest grain weight plant^{-1} of maize (73.44 g) was observed in T_4 treatment. It was observed that yield attributing characters of maize were significantly lower under maize + soybean + grasspea intercropping system which might be responsible for early maturity of maize plants under this system. The result was similar with the findings of Nyasasi and Kisetu (2014) who reported that yield contributing characters such as grain weight $plant^{-1}$ of maize varied significantly due to different intercropping systems.



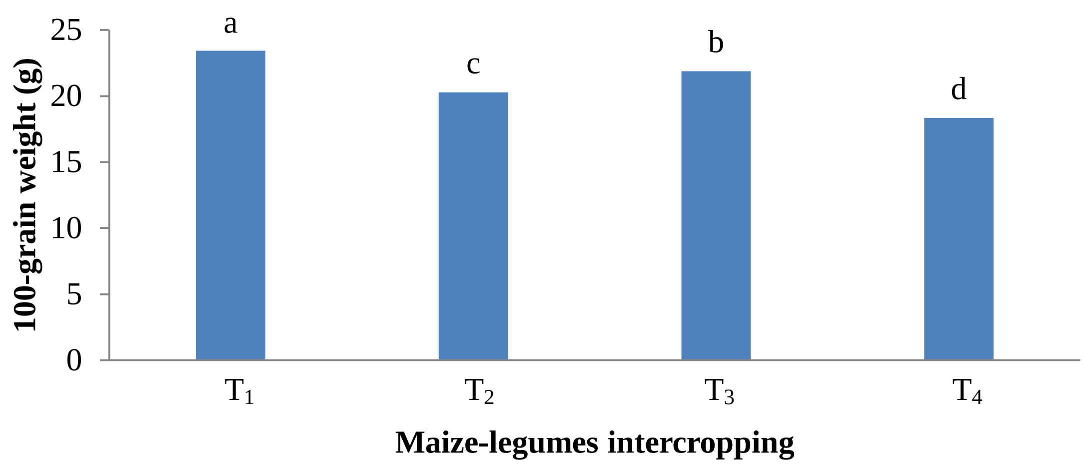
In the bar graph, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, T_1 = sole hybrid maize cropping, T_2 = hybrid maize + soybean, T_3 = hybrid maize + grasspea and T_4 = hybrid maize + soybean + grasspea.

Figure 7. Effect of maize-legumes intercropping on grain weight $plant^{-1}$ of maize

4.8 100-grain weight (g)

100-grain weight of maize was significantly varied among different cropping systems (Figure 8). It was noticed that due to different treatments the 100-grain weight of maize varied between 18.33 g to 23.42 g (Figure 8). Experimental result revealed that, the highest 100-grain weight of maize (23.42 g) was observed in T_1 (sole maize) treatment, while it was observed that T_4 (maize + soybean + grasspea) treatment recorded significantly lower 100-grain weight as compared to all other intercropping systems in this study. It may be because of the reason that the peak demand periods of the two crops for light, nutrients and water were different and there was optimum utilization of physical resources. This resulted in better growth and development of maize crop when grown alone, as compared to intercropping. In intercropping system, the yield attributes were reduced, this indicated that adverse effect of intercropping commenced at an early period of growth affecting development and floral initiation and consequently reduced number of grains cob^{-1}, 100-grain weight and grain yield of maize. Similar result also observed by

Uddin *et al.* (2010) who observed significant reduction in thousand grain weight of maize under maize + spinach intercropping system over sole maize.



In the bar graph, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, T_1 = sole hybrid maize, T_2 = hybrid maize + soybean, T_3 = hybrid maize + grasspea and T_4 = hybrid maize + soybean + grasspea.

Figure 8. Effect of maize-legumes intercropping on 100-grain weight of maize

4.9 Systematic grain yield (t ha^{-1})

Grain yield of a crop is resultant of interaction of different factors. The final objectives of agronomic studies are to optimize the grain yield. Grain yield of a crop depends on dry matter accumulation during vegetative phase and distributed among various sinks. Data on grain yield of different treatments are presented in Table 1, which showed that influence of different intercropping systems significantly influenced systematic grain yield of different treatments. According to the experimental result it was noticed that among different treatments, the highest systematic grain yield (9.37 t ha^{-1}) was observed in T_4 treatment, while the lowest systematic grain yield (7.97 t ha^{-1}) was observed in T_1 treatment. Intercropping of cereal and legume can improve phosphorus and nitrogen use efficiency for crop growth and grain yield compared to sole crops. Enhanced soil phosphorus and nitrogen acquisition by root activity of either intercropped legume or cereal has been proposed as a mechanism of facilitation. It has also been reported that facilitation was more pounced by interspecific competition when phosphorus and nitrogen are more limiting for crop growth. Biomass, grain yield and consequently the taken up amount of phosphorus and nitrogen of intercropped cereals were significantly increased compared to those observed as sole crop as a result the highest systematic grain yield were observed in intercropping treatment compared to sole crop treatment. Undie *et al.* (2012) reported that intercropping maize with soybean in one growing season had no significant effect on grain yield of maize but maize grain and soybean yields were reduced by 6% and 32%, respectively, compared to sole cropping.

Table 1. Effect of maize-legumes intercropping on the production of systematic grain yield

Treatments	Systematic grain yield (t ha^{-1})			
	Maize	**Soybean**	**Grasspea**	**Total**
T_1 (sole hybrid maize)	7.97	0	0	7.97 c
T_2 (maize + soybean)	7.43	1.51	0	8.94 b
T_3 (maize + grasspea)	7.52	0	1.16	8.68 b
T_4 (maize + soybean + grasspea)	7.16	1.29	0.92	9.37 a
$LSD_{(0.05)}$	-	-	-	0.31
CV(%)	-	-	-	1.75

In the column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.

4.10 Systematic stover yield (t ha^{-1})

The stover yield of various treatments, demonstrated that the influence of different intercropping systems significantly influenced systematic stover yield. It was revealed from the experimental result that, in case of systematic stover yield, the highest systematic stover yield (17.11 t ha^{-1}) was observed in T_4 treatment, while the lowest systematic stover yield (11.77 t ha^{-1}) was observed in T_1 treatment (Table 2). The result was similar with the findings of Ashish *et al.* (2015) who reported that the maize grain, stover and biological yield under maize + mashbean intercropping system were 4.0, 2.5 and 3.0 % respectively higher as compared to sole planting.

Table 2. Effect of maize-legumes intercropping on the production of systematic stover yield

Treatments	Systematic stover yield (t ha^{-1})			
	Maize	**Soybean**	**Grasspea**	**Total**
T_1 (sole hybrid maize)	11.77	0	0	11.77 d
T_2 (maize + soybean)	10.39	4.84	0	15.23 b
T_3 (maize + grasspea)	10.82	0	3.79	14.61 c
T_4 (maize + soybean + grasspea)	10.25	4.18	2.68	17.11 a
$LSD_{(0.05)}$	-	-	-	0.56
CV(%)	-	-	-	0.78

In the column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.

4.11 Systematic biological yield (t ha^{-1})

The data on systematic biological yield under maize based intercropping system have been presented in Table 3. The data clearly reveal that the crop configuration of maize based intercropping system had a significantly effect on the production of systematic biological yield. The maximum systematic biological yield (26.48 t ha^{-1}) was obtained under T_4 (maize + soybean + grasspea) treatment. On the other hand, the lowest systematic biological yield (19.74 t ha^{-1}) was obtained under T_1 (sole maize). Intercropping can help to improve soil health by increasing the diversity of soil organisms and by providing a more stable environment for plant growth. This can lead to increased nutrient availability and improved water holding capacity, which can both contribute to higher yields to its associated crops thereby influence biological yield compared to sole cropping. The result was similar with the findings of Ashish *et al.* (2015) who reported that the maize grain, stover and biological yield under maize + mashbean intercropping system were 4.0, 2.5 and 3.0 % respectively higher as compared to sole planting. Hamdalla *et al.* (2014) reported that intercropped maize plants with cowpea, exhibited greater potentiality and resulted in higher values of most of the studied criteria viz., plant height, number of cobs $plant^{-1}$, number of rows cob^{-1}, number of grains row^{-1}, grain weight cob^{-1}, 100–grain weight and straw, grain and biological yields.

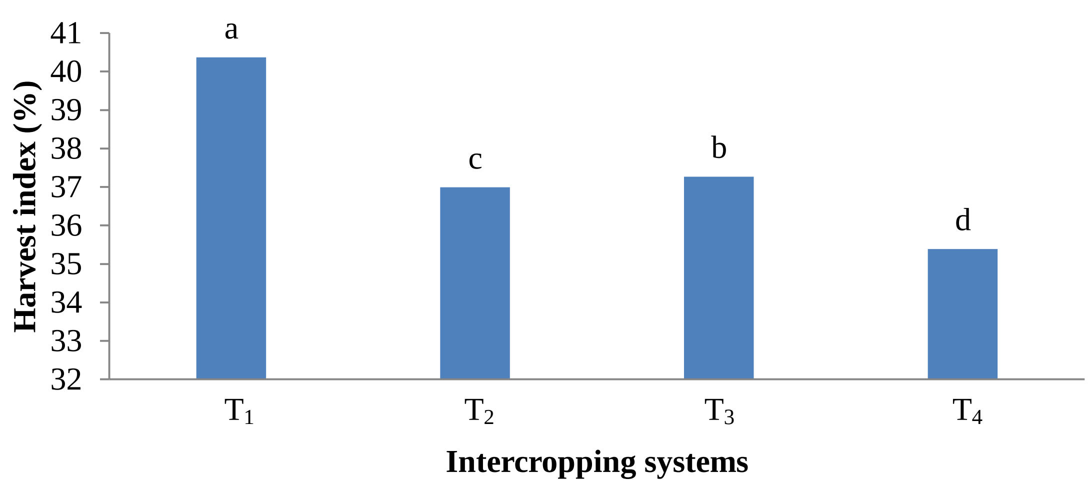
Table 3. Effect of maize-legumes intercropping on the production of systematic biological yield

Treatments	Systematic biological yield (t ha^{-1})			
	Maize	Soybean	Grasspea	Total
T_1 (sole hybrid maize)	19.74	0	0	19.74 d
T_2 (maize + soybean)	17.82	6.35	0	24.17 b
T_3 (maize + grasspea)	18.34	0	4.95	23.29 c
T_4 (maize + soybean + grasspea)	17.41	5.47	3.6	26.48 a
$LSD_{(0.05)}$	-	-	-	0.39
CV(%)	-	-	-	0.84

In the column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability.

4.12 Harvest index (%)

Different maize based intercropping systems significantly influenced harvest index (Figure 9). According to the experimental result the highest harvest index (40.37%) was observed in T_1 treatment, while the lowest harvest index (35.39%) was observed in T_4 treatment. The minimum harvest index in intercropping treatment might be due to more competition of associate crop for light, solar radiation, soil moisture and nutrient during crop growth period compared to sole cropping.



In the bar graph, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, T_1 = sole hybrid maize, T_2 = hybrid maize + soybean, T_3 = hybrid maize + grasspea and T_4 = hybrid maize + soybean + grasspea.

Figure 9. Effect of maize-legumes intercropping on harvest index of systematic yield

4.13 Economic analysis

A crucial factor in choosing the best agricultural community-acceptable solutions that were also economically feasible was economic analysis. The cost of cultivation, net and gross returns, as well as the benefit cost ratio of the different treatment combinations investigated in the current study are shown in (Table 4).

4.13.1 Cost of cultivation

Economic analysis was a significant criterion in selecting the most efficient agricultural community-acceptable solutions that were also economically viable. The cultivation costs, net and gross returns, and benefit cost ratios of the various treatment combinations examined in the current research are shown in (Table 4). The T_4 (maize + soybean + grasspea) treatment recorded the highest cultivation costs (Tk. 178451). While the T_1 (sole maize) treatment combination recorded the lowest cultivation cost (Tk. 166292).

4.13.2 Gross return

Gross returns in the current inquiry varied from Tk. 318800 to Tk. 507400 for various treatment combinations. Out of all the treatment examined, T_4 (maize + soybean + grasspea) treatment recorded the greatest gross returns of Tk. 507400 while T_1 (sole maize) treatment recorded the lowest gross returns of Tk. 318800 (Table 4).

4.13.3 Net return

The T_4 (maize + soybean + grasspea) treatment recorded the highest net returns per hectare of Tk. 328949 when various systems were studied, while the T_1 (sole maize) treatment recorded the lowest net returns of Tk. 152508 (Table 4).

4.13.4 Benefit-cost ratio (BCR)

From all the treatment examined in this experiment, T_4 (maize + soybean + grasspea) treatment recorded the greatest benefit-cost ratio of 2.84, while the T_1 (sole maize) treatment recorded the lowest benefit-cost ratio of 1.92 (Table 4).

Table 4. Economic analysis of maize-legumes intercropping as influenced by different treatments

Treatments	Systematic grain yield ($t\ ha^{-1}$)			Total cost of production (Tk.)	Gross return ha^{-1} (Tk.)	Net return ha^{-1} (Tk.)	Benefit -Cost Ratio (BCR)
	Maize	Soybean	Grass pea				
T_1	7.97	0	0	166292	318800	152508	1.92
T_2	7.43	1.51	0	175488	448200	272712	2.55
T_3	7.52	0	1.16	175488	416800	241312	2.38
T_4	7.16	1.29	0.92	178451	507400	328949	2.84

Here, T_1 = sole hybrid maize, T_2 = hybrid maize + soybean, T_3 = hybrid maize + grasspea and T_4 = hybrid maize + soybean + grasspea.

Selling price: Maize seed - Tk. 40 kg^{-1}, Soybean seed - Tk. 100 kg^{-1} and Grasspea seed - Tk. 100 kg^{-1}.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the agronomy field of Sher-e-Bangla Agricultural University, Dhaka during the period from October-2021 to February-2022 in Rabi season, to study the effect of maize-legumes intercropping on growth and yield of maize. The experiment consisted of a single factor and followed Randomized Complete Block Design (RCBD) with three replications. Different intercropping systems *viz:* T_1 = sole hybrid maize, T_2 = hybrid maize + soybean, T_3 = hybrid maize + grasspea and T_4 = hybrid maize + soybean + grasspea. For the purpose of evaluating the experimental outcomes, data on various parameters were evaluated. The analysis of various parameter data revealed significant differences in maize growth and yield, as a result of different intercropping systems.

Growth and yield of maize significantly influenced due to the effect of intercropping system. Experimental result revealed that, the highest the highest plant height of maize (223.11 cm), total dry matter plant^{-1} (186.93 g), cob length (16.27 cm), cob diameter (5.03 cm), number of rows cob^{-1} (15.99), number of grains cob^{-1} (420.66), grain weight plant^{-1} (109.19 g) and 100-grain weight (23.42 g) were observed in T_1 (sole maize) treatment. However, the highest systematic grain yield (9.37 t ha^{-1}), systematic stover yield (17.11 t ha^{-1}) and systematic biological yield (26.48 t ha^{-1}) were observed in T_4 (maize + soybean + grasspea) treatment. The lowest plant height (176.78 cm), lowest total dry matter plant^{-1} (164.56 g), cob length (11.93 cm), cob diameter (3.8 cm), number of rows cob^{-1} (11.33), grains cob^{-1} (223.09), grain weight plant^{-1} (73.44 g) and 100-grain weight (18.33 g) were observed in T_4 (maize + soybean + grasspea) treatment. However, the lowest systematic grain yield (7.97 t ha^{-1}), systematic stover yield (11.77 t ha^{-1}) and systematic biological yield (19.74 t ha^{-1}) were observed in T_1 (sole maize). In terms of economic return, the highest benefit-cost ratio (BCR) (2.84) was observed in T_4 (maize + soybean + grasspea), while the lowest benefit-cost ratio (BCR) (1.92) was observed in T_1 (sole maize).

Conclusion

Based on the above findings, experimental results revealed significant differences in respect of maize growth and yield, as a result of different intercropping system. However, considering the above all facts, it may be concluded that among different intercropping system sole hybrid maize (T_1) treatment seems promising for increasing growth and yield contributing characteristics of maize compared to other treatments. However, maximum systematic grain yield (9.37 t ha^{-1}), stover yield (17.11 t ha^{-1}) and biological yield (26.48 t ha^{-1}) were observed in maize + soybean + grasspea (T_4) intercropping system. Furthermore, it was observed that the highest economic return i.e. benefit cost ratio (BCR) (2.84) was also found in maize + soybean + grasspea (T_4) treatment. Therefore, it among different intercropping systems, maize + soybean + grasspea was found to be best intercropping system for higher grain production and economic return compared to other treatments.

Recommendations

Considering the results of the experiment, further studies in the following areas are suggested:

- Further experiments could be done with bigger plot sizes and with sole cropping treatments of legume companion crops.
- Maize and other types of legumes intercropping practices may be taken for further experiments to get more accurate result.
- Studies of similar nature could be carried out in different agro-ecological zones (AEZ) in different seasons of Bangladesh for the evaluation of zonal adaptability.

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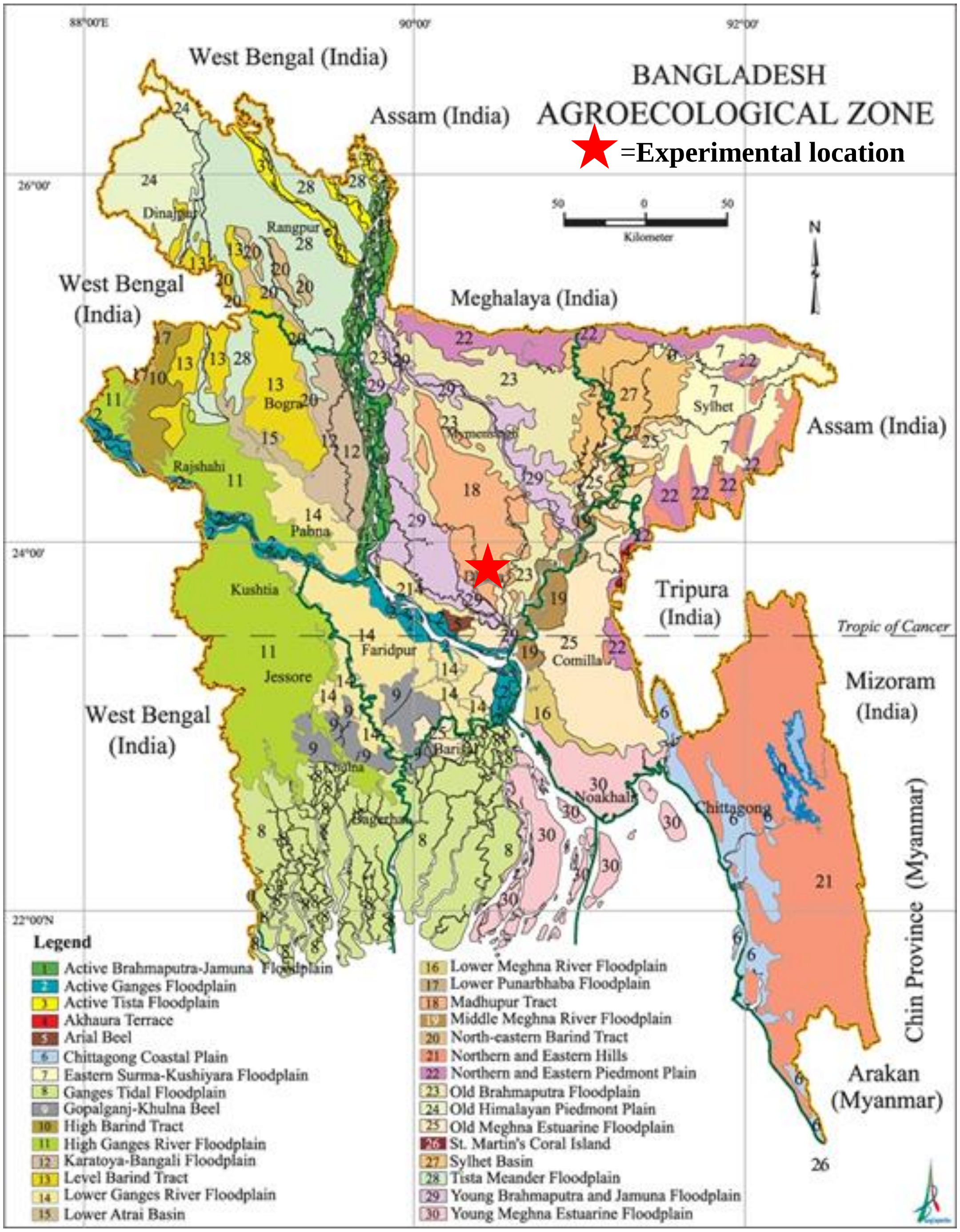
APPENDICES

Appendix-I. Map showing the experimental location under study



Appendix-II. Monthly meteorological information during the period from October, 2021 to February, 2022.

Year	Month	Air temperature (°C)		Relative humidity (%)	Average rainfall (mm)
		Maximum	Minimum		
2021	October	31.2	23.9	76	52 mm
	November	29.6	19.8	53	00 mm
	December	28.8	19.1	47	00 mm
2022	January	25.5	13.1	41	00 mm
	February	25.9	14	34	7.7 m

Source: Meteorological Centre, Agargaon, Dhaka (Climate Division)

Appendix-III. Soil characteristics of the experimental field

A. Morphological features of the experimental field

Morphological features	Characteristics
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Location	Sher-e-Bangla Agricultural University Agronomy Research Field, Dhaka
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0-15 cm depth)

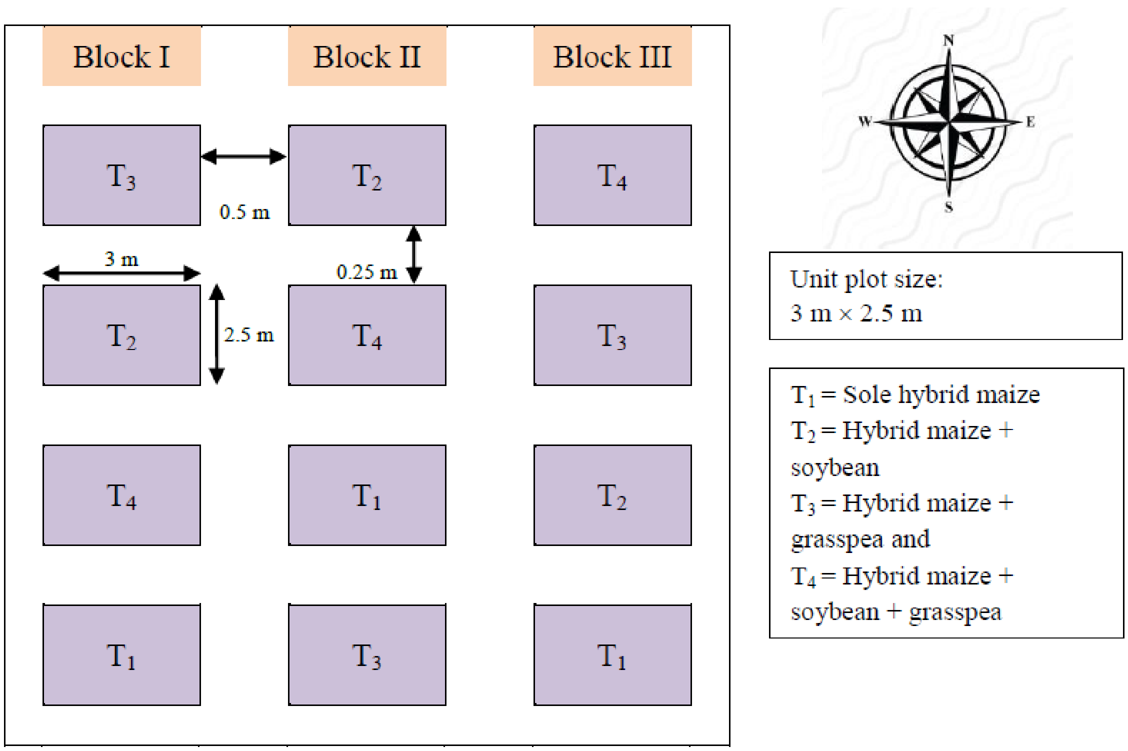
Physical characteristics

Constituents	Percent
Clay	29
Sand	26
Silt	45
Textural class	Silty clay

Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

Source: Soil Resource Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

Appendix-IV. Layout of the experimental field



Appendix-V. Analysis of variance of the data on plant height, Total dry matter plant^{-1}, cob length and cob diameter of maize at harvest

Source	DF	Plant height	Total dry matter plant^{-1}	Cob length	Cob diameter
Replication (R)	2	24.45	3.40	0.69	0.03
Treatment	3	1182.40*	264.04*	10.18*	0.83*
Error	6	469.55	44.58	1.27	0.02

*: Significant at 0.05 level of probability
^{NS}: Non-significant

Appendix-VI. Analysis of variance of the data on number of rows cob^{-1}, number of grains cob^{-1}, grains weight plant^{-1} and 100 grain weight of maize

Source	DF	No. of rows cob^{-1}	No. of grains cob^{-1}	Grain weight plant^{-1} (g)	100-grain weight (g)
Replication (R)	2	1.58	13.91	8.04	4.78
Treatment	3	7.22*	20844.50*	715.75*	14.31*
Error	6	1.14	51.05	12.18	0.45

*: Significant at 0.05 level of probability
^{NS}: Non-significant

Appendix-VII. Analysis of variance of the data on systematic grain, stover, biological yield and harvest index of different treatments

Source	DF	Grain yield	Stover yield	Biological yield	Harvest index
Replication (R)	2	0.01	0.08	0.03	0.00
Treatment	3	1.03*	14.68*	23.49*	13.00*
Error	6	0.02	0.01	0.04	0.04

*: Significant at 0.05 level of probability
^{NS}: Non-significant

Appendix-VIII. Per hectare production cost of different treatment

A. Input cost (Tk. ha^{-1})

Treatments	Labour	Ploughing	Maize Seed	Soybean seed	Grasspea seed	Irrigation	Pesticides	Manure and fertilizer	Total input cost
T_1 (sole hybrid maize)	30000	12000	1200	0	0	10000	9000	21170	83370
T_2 (maize + soybean)	30000	12000	1200	2500	0	10000	9000	26430	91130
T_3 (maize + grasspea)	30000	12000	1200	0	2500	10000	9000	26430	91130
T_4 (maize + soybean + grasspea)	30000	12000	1200	2500	2500	10000	9000	26430	93630

Note: Urea - Tk. 20 kg^{-1}, TSP - Tk. 22 kg^{-1}, MoP - Tk. 15 kg^{-}1 and, Cowdung - Tk. 1 kg^{-1}
Selling price: Maize seed - Tk. 40 kg^{-1}, Soybean seed - Tk. 100 kg^{-1} and Grasspea seed - Tk. 100 kg^{-1}.

B. Overhead cost (Tk. ha^{-1})

Treatments	Cost of lease of land for 6 months (13.5% value of land Tk. 1,000,000 year^{-1})	Miscellaneous cost (Tk. 5% of the input cost)	Interest on running capital for 6 months (Tk. 13.5% of cost year^{-1})	Subtotal (Tk.) (B)	Total cost of production (Tk. ha^{-1}) [Input cost (A) + overhead cost (B)]
T_1 (sole hybrid maize)	67500	4168	11254	82922	166292
T_2 (maize + soybean)	67500	4556	12302	84358	175488
T_3 (maize + grasspea)	67500	4556	12302	84358	175488
T_4 (maize + soybean + grasspea)	67500	4681	12640	84821	178451

PLATES

Plate 1. Layout of the experimental field

Plate 2. Germination of maize seedlings

Plate 3. Germination of soybean seedlings

Plate 4: Weeding

Plate 5. Data collection