INFLUENCE OF SOWING PATTERN AND NITROGEN LEVEL ON THE PRODUCTIVITY UNDER MAIZE-CHICKPEA INTERCROPPING SYSTEM

A THESIS

By

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Registration No. 07-02596

Session: January-June, 07

Submitted to the Faculty of Agriculture

Sher-e-Bangla Agricultural University, Dhaka,

In partial fulfilment of the requirements

For the degree of

MASTER OF SCIENCE (M.S)

IN

AGRONOMY

SEMESTER: JANUARY-JUNE, 07

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CERTIFICATE

This is to certify that the research work entitled, "**INFLUENCE OF SOWING PATTERN AND NITROGEN LEVEL ON THE PRODUCTIVITY UNDER MAIZE-CHICKPEA INTERCROPPING SYSTEM**" 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 in AGRONOMY,** embodies the result of a piece of bonafide research work successfully carried out by MD. MOHIBUR RAHMAN bearing Registration No. **07-02596** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: 26/6/08
Place: Dhaka, Bangladesh

Prof. Dr. Md. Fazlul Karim
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Dedicated to My Beloved Parents

ACKNOWLEDGEMENTS

All praises are devoted to Almighty Allah, who is the supreme authority of this universe, and who enabled the author to complete the research work and submit the thesis for the degree of Master of Science (M.S) in Agronomy.

The author would like to acknowledge the untiring inspiration, encouragement and invaluable guidance provided by his respected teacher and supervisor Prof. Dr. Md. Fazlul Karim, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka. His constructive criticism, continuous supervision and valuable suggestions were helpful in completing the research and writing up the manuscript.

The author would like to express his heartiest appreciation, ever indebtedness and deep sense of gratitude to his co-supervisor Associate Prof. Dr. H. M. Tariq Hossain, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his sincere advice, constant supervision, valuable suggestions and factual comments in upgrading the quality of the research work and in preparing the manuscript.

The author would like to express his heartiest appreciation, ever indebtedness and deep sense of gratitude to Prof. Dr. Md. Jafar Ullah, Chairman, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his kind permission to allow the departmental and laboratory facilities.

The author expresses his thanks to all other staff members of the farm of Sher-e-Bangla Agricultural University, Dhaka for their help in conducting the experiment. The author feel proud to express his unreserved gratitude to Sagar, Mosharef, Masud, Mony, Babu, Jayanta, Tanu, Shanto, Adil, Mizan, Raihan, Mushfiq, Mukul, Kashem, Badshah, Monir for their heartfelt cooperation during research period and writing up the manuscript.

The Author

ABSTRACT

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka during the period of December, 2007 to May, 2008 to study the influence of sowing pattern and nitrogen levels on the productivity under maize-chickpea intercropping system in a Randomized Complete Block Design (RCBD) with 3 replications. The experiment comprised seven treatments viz, T_1 = Sole maize normal row (MNR) with 120 kg N ha^{-1}, T_2 = Sole maize paired row (MPR) with 120 kg N ha^{-1}, T_3 = MNR + 2 chickpea rows with 120 kg N ha^{-1}, T_4 = MNR + 2 chickpea rows with 90 kg N ha^{-1}, T_5 = MPR + 5 chickpea rows with 120 kg N ha^{-1}, T_6 = MPR + 5 chickpea rows with 90 kg N ha^{-1} and T_7 = Sole chickpea with 20 kg N ha^{-1}. The results revealed that T_5 showed better performance than the other intercropped treatments and sole crops in respect of total grain yield and economic benefit. From the economic point of view, the sole crops showed the lowest performance. Maximum grain yield of maize (4506 kg ha^{-1}) and chickpea (1623 kg ha^{-1}) were obtained in T_1 and T_7, respectively. The highest maize equivalent yield (7664 kg ha^{-1}) was found in T_5 and the lowest in T_2 (4192 kg ha^{-1}). The highest LER (1.70) was observed in T_5, which also gave maximum net return (91419 Tk ha^{-1}) with the maximum BCR (2.96) whereas; the lowest LER (1.37) was recorded in T_4 in intercropping situation.

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ACRONYMS

AEZ	Agro-ecological Zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
cm	Centimeter
Contd.	Continued
CV	Co-efficient of variation
et al.	and others
FAO	Food and Agricultural Organization
g	Gram
ha	Hectare
HI	Harvest Index
i.e.	that is
kg	Kilogram
LSD	Least significant difference
MP	Muriate of Potash
N	Nitrogen
No.	Number
RCBD	Randomized Complete Block Design
$t\ ha^{-1}$	ton per hectare
TSP	Triple Superphosphate
UNDP	United Nations Development Programme
viz.	namely
%	Percentage
^{0}C	Degree Celsius

Chapter 1

INTRODUCTION

INTRODUCTION

Maize (*Zea mays* L.) is one of the leading cereals of the world. It originates from sub-tropical regions, probably from the highlands of Mexico and today it is a leading crop in many temperate regions (Miedema, 1982). Maize, area is increasing in Bangladesh for its higher yield potentiality and well fitted in the existing agro-climatic condition and cropping patterns of Bangladesh.m Chickpea (*Cicer arietinum* L.) is a winter pulse crop belonging to the sub-family Papilionaceae of the family Leguminosae. Probably the geographical origin of chickpea was in South-West Asia and it is distributed throughout India and Europe. Chickpea known as gram, bengal gram or chola in Bangladesh, is an important grain legume with high value of protein. Chickpea is an important source of human food as well as animal feed and it also helps in managing soil fertility particularly in dry land (Sharma and Jodha, 1984).

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 a). The main advantage for the use of legumes in intercropping and mixed cropping is as the saving of N-fertilizer. 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. Chickpea can mobilize organic P in both hydroponic and soil cultures, leading to an interspecific facilitation in utilization of organic P in maize/chickpea intercropping (Li *et al.*, 2004). In the tropical and sub-tropical regions, cereal-legumes intercropping are the most popular practices because of its many additional advantages (Willey, 1979 a; Karim *et al.*, 1990). Intercropping becomes more productive and economical when both the crops differ with genetic makeup, 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 (Isoda *et al*., 1992; Takahashi and Nakaseko, 1993). 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. 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. Despite many advantages of cereal-legumes intercropping systems all crop combination are not equally profitable (Shah *et al*., 1991).

Instead of uniform row of maize, paired row planting of maize is an advantageous management which ultimately improves the gross return by accommodately different legume crops between the wider spaces of paired maize rows. Sorghum gave maximum yield and monetary advantages when grown between paired rows of maize. The component crops being grown in wider spaces of paired row system enable the plants to utilize efficiently the soil nutrients and solar radiation (Singh, 1981). In cereal-legumes intercropping systems, legumes are considered as nitrogen economy and favored the yield of component crop. However, the extent of biological nitrogen fixation of different kinds of legumes are not generally same in a particularly environment and often varied with the change of crop environments. The quantity of nitrogen fixed by the legumes component in cereal-legume intercropping systems depends on species, morphology and the competitive abilities of the component crops (Ofori and Stern, 1987). Therefore, the quantity of nitrogen saved by different kinds of legumes also determines the economics of cereal-legume intercropping systems.

Sufficient information on influences of sowing pattern and nitrogen level on the productivity under maize-chickpea intercropping system are not available. There is a lot of research information on cereal-legumes intercropping systems but there is little or no documented research reports on the influence of row arrangement and nitrogen level on the productivity under maize-chickpea intercropping system. So, the research work was undertaken keeping in mind the following objectives:

I) To study the influences of sowing pattern and nitrogen level on the yield and yield attributes of maize and chickpea under maize-chickpea intercropping system and

II) To observe the economic performance of intercropping maize with chickpea as sole and intercrop combination under different planting pattern.

Chapter 2
REVIEW OF LITERATURE

REVIEW OF LITERATURE

The present experiment was carried out to study the influence of sowing pattern and nitrogen level on the productivity under maize-chickpea intercropping system. The research works related to the present study are scanty in Bangladesh although some relevant researches have been done in other countries of the world. Thus, the research works relevant to the present study have been reviewed and presented in this chapter:

Jahansooz *et al.* (2007) showed that the lack of a yield advantage of mixed cropping was associated with poor canopy development and low yielding capacity of chickpea; it was unable to compensate for its reduced population density in the mixture. Grain yield for chickpea in the mixed crop (chickpea-maize) averaged just 29% that of its sole crop (chickpea-sugarcane), whereas wheat grown in mixture (wheat-maize) produced 72% the yield for wheat- sugarcane. Supplementary irrigation from early spring onwards in 1995 increased yield for chickpea-maize by 44% over that of chickpea- sugarcane, while yield for wheat-maize fell to 65% that for wheat-sugarcane. Every millimeter of irrigation water increased yield by 10.0, 3.8 and 12.5 kg ha^{-1} for wheat- sugarcane, mixed crop and chickpea- sugarcane, respectively. Mixed cropping did not affect the time taken by either wheat or chickpea to attain maximum growth rate, flowering or maturity. The land equivalent ratio (LER) based on grain yields for wheat-chickpea intercropping were 1.01 in 1994, 1.02 without irrigation in 1995, and 1.10 with irrigation in 1995. Neither radiation-use-efficiency nor water-use-efficiency was improved by mixed cropping compared with wheat- sugarcane. The poor performance of the mixed crop was ascribed to its poor canopy development early in the season, especially by the chickpea that resulted in low intercepted PAR and transpiration. It is concluded that there was no advantage of growing wheat and chickpea in mixed crops in southern cereal belts of Australia if total biomass or grain yield is the primary purpose.

For increasing land use efficiency and weed suppression intercropping plays a pivotal role. A field experiment was carried out on wheat (*Triticum aestivum* L. emend. Fiori and Paol)–chickpea (*Cicer arietinum* L.) mono- and intercropping with various weeding (0, 1, or 2 hand-weeding operations) and row spacing (20 or 30 cm) treatments in the eastern plateau region of India over consecutive five winter seasons (1997/2001). Chickpea yield was significantly reduced by wheat when intercropped. However, total productivity and land use efficiency were higher under the intercropping system as compared to monocrops of either species. There was a significant reduction in weed density and biomass for the intercropping system over both monocrops. Wheat facilitated an increase in nodule number and dry weight in chickpea under intercropping over monocrops, moreover, root length of chickpea was greater when intercropped. These findings suggest that intercropping wheat and chickpea increase total productivity per unit area improve land use efficiency and suppress weeds, a menacing pest in crop production. Considering the experimental findings, wheat–chickpea (30 cm) with two weeding may be recommended for yield advantage, higher net income, more efficient utilization of resources, and weed suppression as a biological control in eastern plateau region of India (Banik *et al.*, 2006).

Singh *et al.* (2006) reported that seed treatment (wheat) and wider row spacing (wheat and lentil) resulted in a definite and consistent increase in yields as compared to untreated seed and closer spacing, respectively. Fertilizer and weed management were an important aspect for increasing overall crop productivity. Intercropping of 'raya' with rainfed rabi crops viz. wheat, lentil and chickpea increased the crop yield by 10-

25%, clearly elucidating the beneficial advantage of intercropping under rainfed conditions.

Maize cv. H-216 was intercropped with different combinations of chickpea cv. JG-315, Indian mustard cv. Pusa Bold black gram (*Vigna mungo*) cv. DPU-88-31, soybean cv. JS-335 and sesame cv. Krishna in a field experiment was conducted in Madhya Pradesh, India during the 1997-99. Intercropping maize with soybean and chickpea resulted in the highest mean equivalent maize yield during 1997-1998 (124.24) and 1998-99 (95.33) and the highest gross monetary returns (Rs. 35,318), net monetary returns (Rs. 25.468), land use efficiency (61.5%), production efficiency (Rs. 101.7/ha/day). The highest benefit cost ratio (2.85) was observed with intercropping maize with black gram and chickpea (Thakur, 2003).

Yield and nutrient acquisitions by intercropped wheat, maize and soybean were all significantly greater than for sole wheat, maize and soybean with the exception of K acquisition by maize. Intercropping advantages in yield (40–70% for wheat intercropped with maize and 28–30% for wheat intercropped with soybean) and in nutrient acquisition by wheat resulted from both the border- and inner-row effects. The relative contribution to increasing biomass was two-thirds from the border-row effect and one-third from the inner-row effect. Similar trends were noted for N, P and K accumulation. During the co-growth period, lasting for about 80 days from maize or soybean emergence to wheat harvesting, yield and nutrient acquisition by intercropped wheat increased significantly while those by maize or soybean intercropped with wheat decreased significantly. Comparison of overall N and K acquisition by intercropping with weighted means of those of sole cropping revealed interspecific facilitation in nutrient acquisition during co-growth (Li *et al.*, 2001a).

Three field experiments were conducted at Baiyun in 1997 and at Jingtan in 1997 and 1998 to test the hypothesis in wheat/maize and wheat/soybean intercropping. The rates of dry matter accumulation in the intercropped maize (10.0–20.1 g/m^2 per day) were significantly lower than those in the sole maize (17.1–34.8 g/m^2 per day) during the early stage from 7 May to 3 August, while mostly intercropped with wheat. After 3 August, however, the rates of intercropped maize, increasing to 58.9–69.9 g/m^2 per day, was significantly greater than in sole maize (22.7–51.8 g/m^2 per day) at Baiyun site in 1997 and nutrient acquisition showed the same trends as growth. At Jingtan site in 1998, the disadvantage of the border row of intercropped maize resulted from interspecific competition diminished after wheat harvest and disappeared at maize maturity. It was concluded that there was indeed recovery of growth after wheat harvesting in wheat/maize and wheat/soybean intercropping. However, the recovery was limited under N_0P_0 treatment. The interspecific competition, facilitation and recovery are together contributed to yield advantage of intercropping (Li *et al.*, 2001 b).

A study was conducted in South Africa during the 1998-1999 seasons to evaluate the performance of pigeon pea cultivars with varying maturity periods, with maize in 2 intercropping systems (alley planting and same row planting systems). Short-duration (SD) maize components EWF-2 was intercropped with SD pigeon pea cultivars ICPL 87091 and ICPL 87105 in one trail, and with medium-duration (MD) and long-duration (LD) cultivars ICP 6927 and ICEAP 00040, respectively, in a second trail. Yields of both crops in intercropping systems were generally lower than in monocropping systems. Significant yield reduction was observed under alley intercropping for LD and MD cultivars. Average land equivalent ratio was the same

(1.24) in both systems in the SD trail, while LER in the LD-MD trail was 1.37 under alley intercropping and 1.77 under same row intercropping (Mathews *et al.*, 2001).

The question of the impact of chickpea genotypes differing in potential N fixation on system performance of a chickpea-wheat rotation under dryland conditions is addressed. The results showed the trade-off between the gains or losses in chickpea and wheat yields by introducing chickpea with different traits into the rotation (Robertson *et al.*, 2000).

It was 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 (Singh *et al.*, 1988). Patra *et al.* (1999) observed the increased number of cobs per plant due to temporal complementary in maize-legume association. They 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 vigor might be reduced the yield of intercrop. Patra *et al.* (1990) 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. In cereal-legume intercropping system, yield reduction of legumes has been reported in almost all cases. 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).

An experiment was conducted to study the effect of planting system of 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 6 paired rows of groundnut. Both the former and the later combination gave higher LER (1.44) and net return of Tk. 8719 and 8502/ha, having same benefit cost ratio (Karim *et al.,* 1990). The magnitude of yield advantage of intercropping system could be determined by the use of LER value (Ofori and Stern, 1987). The concept of LER 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).

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. An intercropping experiment with maize and mungbean under different planting patterns and row orientation was conducted where higher maize yield was obtained from intercropping system (Dhingra *et al.*, 1991). Singh (1978) and Reddy and Reddy (1981) did not observe any adverse effect of maize yield due to intercropping with legumes. Singh *et al.* (1986) conducted an intercropping experiment with maize, soybean and blackgram under varying population and nitrogen levels and concluded that yields of the mixed stand with maize at 50,000 plants/ha were higher than maize at 37500 or 75000 plants/ha.

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 chick pea between maize rows. Two years data revealed intercropping of maize grown at a spacing of 25 x 25 cm with two rows of chickpea produced 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 + chickpea, yield gave the highest net return of Tk 12803.00/ha and the highest LER of 1.35 indicating that the mixture was 35% more efficient in terms of land utilization than a sole crop of maize.

Kalra and Gangwar (1980) reported that total productivity was 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 system of maize and legume. 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 legume and fertilized with 120 kg N/ha gave more yield than the application of 80 kg N/ha.

Various spatial arrangements of maize (*Zea mays* L.) were tried in attempt to improve grain yield of a soybean [*Glycine max* (L.) Merr.] intercrop sown in the same row, without substantially reducing the maize yield. The experiment was conducted in 1980 and 1981 in Iowa; U.S.A. Intercropping reduced soybean yields by 87% compared with sole cropping, principally because of reduced plant growth and pod set. Harvest index of soybeans was not altered. Compared with a 70 cm × 30 cm (row × intra-row) plant arrangement, grouping maize plants two or three to a hill in wider intra-row spacing (70 cm × 60 cm, 70 cm × 90 cm) improved soybean growth and pod set, reduced its lodging, and allowed greater seed yield. Widening rows to 87 and 105 cm did not improve soybean performance.

Improved maize growth, as a consequence of a 135 kg/ha N application, reduced intercropped soybean growth and yield. Intercropping without applied N did not reduce maize yield compared with monocropping without N. Hence, the additional soybean yield from intercropping was supplemental. When 135 kg/ha N was applied, however, intercropping tended to reduce maize yield slightly, though not significantly, resulting in a total maize plus soybean yield about the same as for maize monocropping with N. Thus, when N was applied, there was no supplementary legume yield from intercropping (Chui and Shibles, 1984).

Singh (1983) observed that sorghum gave the 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 monetary advantage from groundnut intercropping between paired rows of maize. Maximum benefit occured when component crops are sown in wider row spaces for the all 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). Rathore *et al.* (1980) observed in maize + blackgram intercropping system that paired planting 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.

Yadav (1981) obtained the 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. Rajasekaran *et al.* (1983) concluded 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 kg N/ha. The highest total yield and net return was obtained from maize and groundnut intercropping at the plant population levels of 4.4 x 10^4 maize and 16.6 x 10^4 groundnut plants per hectare with 120 kg N/ha than 30 kg N/ha (Quayyum *et al.*, 1985). Islam (1982) found that the 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 were 103 percent with cowpeas, 16 to 82 percent with mung, 16 to 42 percent with groundnut and 25 to 68 percent with beans (Gunasena *et al.*, 1979). They indicated that yields of all legumes decreased in the intercropping system. Hashem (1983) reported that maize yield was reduced in intercropping with cowpea by 19% at 100% maize + 50% cowpea combination but total yield advantage increased by 25% compare to sole crop of maize. Average increase of total grain production ranged from 29.5 to 92.5 percent as a result of maize + legumes intercropping system (Kalra and Gangwar, 1980). 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/ha and 1,11,111 blackgram plants/ha. But total yield advantage increased by 47 and 55 percent, respectively.

Chapter 3

MATERIALS AND METHODS

MATERIALS AND METHODS

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka during the period from December, 2007 to May, 2008. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and their analyses.

3.1 Experimental site

The experimental site was located under the Agro-ecological zone 28 (Madhupur Tract) having the red brown trace soils and acid basin clay.

3.2 Soil

The soils were slightly acidic in reaction with very low status of organic matter, low moisture holding capacity and low fertility level. Soils were mainly phosphate fixing and low in K. (Appendix I).

3.2 Climate

The crop was grown in winter season when the day length (sunshine period) reduced to 10.5-11.0 hours and there was unexpected rainfall (3.0mm) at beginning of the experiment and also at the time of harvesting (3.5mm).Maximum and minimum temperature were ranged as 24.5°C - 29.6°C and 13.9°C - 21.5°C, respectively during the cropping period. Relative humidity was ranged as 61.0% - 70.6%. The monthly average temperature, humidity, rainfall and sunshine hours prevailed at the experimental area during the cropping season are presented in Appendix II.

3.4 Experimental treatments

The following seven treatments were tested

T_1 = Sole maize normal row (MNR) with 120 kg N/ha

T_2 = Sole maize paired row (MPR) with 120 kg N/ha

T_3 = MNR + 2 chickpea rows with 120 kg N/ha

T_4 = MNR + 2 chickpea rows with 90 kg N/ha

T_5 = MPR + 5 chickpea rows with 120 kg N/ha

T_6 = MPR + 5 chickpea rows with 90 kg N/ha

T_7 = Sole chickpea with 20 kg N/ha

3.5 Experimental design

The experiment was conducted in a Randomized Complete Block Design (RCBD) with 3 replications. Lay out of the experiment following RCBD was done on 09 December, 2007.

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 08 December, 2007 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 Seed sowing

Maize and chickpea seeds were sown in line on 10 December, 2007. Two to three seeds of maize per hill were dibbled at 5 cm depth of the furrows maintaining a hill distance of 25 cm. Chickpea seeds were sown at 5 cm depth in solid lines seeds of

Bornali for maize and BARI chickpea-5 for chickpea. Irrigation was applied in the furrows for the better germination of the seeds.

3.6.3 Gap filling and thinning

Chickpea and maize seed germinated four and five days after sowing (DAS), respectively. Gap filling was done on 20 December, 2007 (10 DAS). Thinning of excess maize and chickpea plants were done at 20 DAS to keep one plant per hill of maize and 10 cm between plants in a chickpea row.

3.6.4 Plant population and planting system

In all the treatments the recommended plant population of maize (55,555 plants per hectare) was maintained. Recommended plant population of chickpea (3,33,333 plants per hectare) as sole crop was maintained by sowing the seeds 30 cm apart between rows and plant to plant distance as 10 cm. Maize was sown in two row orientation like uniform row (UR) and paired row (PR) systems. In UR method, normal spacing (75 cm x 25 cm) was followed. In PR method, two maize rows were sown at 37.5 cm distance and two paired rows were separated by a distance of 150 cm. Plant to plant distance for maize was 25 cm in both the methods. In UR method, two rows of chickpea were sown between the maize rows while in PR method five rows of chickpea were between the two pairs of maize rows.

3.6.5 Weeding

Weeding was done manually on 31 December, 2007 (21 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 @ 2 g per kg seed was used before seed sowing for seed treatment. Diazinon 60 EC @ 2.5 ml per liter, Sumitheon @ 2 ml per liter water at 15 and 35 DAS were applied to prevent chickpea plants from the attach of caterpillar, pod borer etc. There was no diseases infestation in maize. Earthling up was practiced against lodging of maize plants.

3.6.7 Application of fertilizer

Maize plants received a uniform application of 65, 50, 18, 1 kg/ha of P_2O_5, K_2O, S and B as TSP, MP, Gypsum, and Borax, respectively. Maize treatments as sole and intercropped were given nitrogen fertilizer as per treatments. Sole chickpea received 20 kg nitrogen per hectare. Half amount of urea and full quantity of TSP, MP, Gypsum, and Boric acid were mixed with soil at the time of sowing maize and chickpea treatments. The remaining quantity of urea was applied in maize rows in two equal splits at 25 and 45 DAS as side dressing. The sole chickpea received 20 kg N/ha as basal application. Additional fertilizer was not applied for chickpea as intercrop.

3.6.8 Irrigation

Irrigation was done at 25 days interval.

3.7 Data recorded at harvest

3.7.1 Crop characters

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

Data for Maize

i) Plant height (cm)
ii) Cob length (cm)
iii) No. of grains per cob
iv) 1000-grain weight (g)
v) Grain yield (kg/ha)
vi) Stover weight (kg/ha)
vii) Harvest index (HI)

Data for chickpea

i) Plant height (cm)
ii) No. of branches per plant
iii) No. of pods per plant
iv) No. of seeds per pod
v) 1000-seed weight (g
vi) Seed yield (kg/ha)
vii) Stover yield (kg/ha)
viii) Harvest index (%)

3.7.2 Grain yield

An area of 13.5 m^2 (4.5 m x 3 m) was harvested from both sole and intercropped treatments of chickpea and maize. The harvested area included six maize rows in sole and intercrop, 15 chickpea rows in sole and 10 in intercrop treatments. Chickpea was harvested on 27 April, 2008. Maize was harvested on 5 May, 2008. 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 chickpea was recorded. Maize stover was dried and per plot weight was recorded. The grain yield of maize and chickpea and stover yield of maize and chickpea 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.

$$\text{Maize equivalent yield} = Ym + \frac{Yi \times Pi}{Pm}$$

Where,

Ym = Yield of maize (kg/ha)

Yi = Yield of intercrop chickpea (kg/ha)

Pi = Price of intercrop chickpea (Tk/ha)

Pm = Price of maize (Tk/ha)

3.8 Harvest index

Harvest index is the relationship between economic yield (grain yield) and biological yield (Gardner *et al.*, 1985). It was calculated by using the following formula:

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

3.9 Relative yield

It was determined with following formula:

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

3.10 Land equivalent ratio (LER)

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

$$LER = \frac{Ymc}{Ym} + \frac{Ycm}{Yc}$$

Where,
Ymc = Yield of maize when intercropped with chickpea

Ym = Yield of sole maize

Ycm = Yield of chickpea when intercropped with maize

Yc = Yield of sole chickpea

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 chickpea 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 collected on different parameters under the experiment were statistically analyzed to obtain the level of significance using the computer MSTAT package program developed by Russel (1986). The differences between pairs of means were compared by Least Significant Difference (LSD) at 5 % level of significance as stated by Gomez and Gomez (1984).

Chapter 4
RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The results obtained from the experiment are described and discussed in this chapter. The crop characters of maize and chickpea along with their yield and the evaluation of profitability of intercropping system due to the influence of row arrangement and nitrogen level under maize-chickpea intercropping system have been presented and discussed under separate heads and sub-heads as follows:

4.1 Crop characters of maize

4.1.1 Plant height

Plant height is a vertical spatial distribution of plant. Plant height was significantly varied among the treatments (Table 1). The tallest (226.67 cm) plant was recorded in treatment T_1 (sole maize MNR with 120 kg N ha^{-1}) and the second tallest (218.3 cm) was with treatment T_2 (MPR with 120 kg N/ha). The shortest (201.00 cm) plant was recorded in treatment T_6 (MPR + 5 rows of chickpea with 90 kg N/ha). Rest of the treatments showed intermediate status. From the above results, it appears that the higher plant height was recorded in sole crop. Karim *et al.* (1990) found the similar results which supported the present study.

4.1.2 Cob length

Significant variation in cob length was noticed in different treatments (Table 1). The longest (22.0 cm) cob was observed in treatment T_1. The second maximum cob length (19.00) obtained with T_2 and followed by T_3 (18.67) and T_5 (18.00). The shortest (17.33 cm) cob was observed both in treatment T_4 and T_6. From the results, it appears that cob length was longer in sole maize. The above results of cob length are also in full agreement with Patra *et al.* (1999).

4.1.3 Number of grains per cob

Grains cob^{-1}, the most important yield attribute, was significantly different among the treatments (Table 1). Treatment T_1 produced the highest number of grains cob^{-1} (395.00). T_2 gave the second highest number of grains (363.33) per cob. On the other hand, treatment T_6 produced the lowest number of grains cob^{-1} (308.00) and followed by T_4 (312.33). This result also revealed that sole maize had higher number of grains cob^{-1} than the intercrop. From the above result it may be said that sole maize planting dominated over paired row maize planting in respect of number of grains cob^{-1}. The above results of number of grains per cob are also in full agreement with Patra *et al.* (1999).

4.1.4 1000-grain weight

Thousand grain weights represent grain size. The effect of various treatments on 1000-grain weight was significant (Table 1). Treatment T_3 showed the highest 1000-grain weight (311.28 g) due to bigger grain size and followed by all other treatments except T_2, which produced 238.64 g weight of 1000 grain. From this result, it appears that 1000-grain weight is higher in intercropping maize than the sole maize. Dhingra et al. (1991) reported that maximum 1000-grain weight was obtained from intercropping of maize with mungbean which was in full agreement with the present study.

4.1.5 Grain yield

There was a remarkable difference among the treatments in respect of grain yield. Treatment, T_1 produced the highest grain yield (4506 kg ha^{-1}). Paired row sole maize produced the second highest grain yield (4192 kg ha^{-1}). On the other hand, T_6 produced the lowest grain yield (3113 kg ha^{-1}) which is

Table 1: Influence of sowing pattern and different nitrogen levels on the plant characters of maize as a sole and intercropped with chickpea

Treatment	Plant height (cm)	Cob length (cm)	No. of grains Cob^{-1}	1000-grain wt. (g)	Yield ($Kg\ ha^{-1}$)		Harvest index (HI) (%)
					Grain	Stover	
T_1	226.67	22.00	395.00	300.47	4506	5595	44.61
T_2	218.33	19.00	363.33	238.64	4192	5218	44.54
T_3	209.67	18.67	327.67	311.28	3785	4863	43.76
T_4	203.67	17.33	312.33	305.37	3163	4577	40.86
T_5	207.67	18.00	346.00	295.89	3942	5228	42.99
T_6	201.00	17.33	308.00	309.05	3113	4763	39.52
$LSD_{(0.05)}$	2.23	1.4	7.45	23.53	103.2	111.5	1.01
CV (%)	0.58	4.10	1.20	4.41	1.88	1.22	1.30

Values with common letter (s) within a column do not differ significantly at 5% level of significance

T_1 = Sole maize normal row (MNR) with 120 kg N/ha

T_2 = Sole maize paired row (MPR) with 120 kg N/ha

T_3 = MNR + 2 chickpea rows with 120 kg N/ha

T_4 = MNR + 2 chickpea rows with 90 kg N/ha

T_5 = MPR + 5 chickpea rows with 120 kg N/ha

T_6 = MPR + 5 chickpea rows with 90 kg N/ha

about 45% lower than that of T_1 (Table 1). From this result, it was observed that sole maize with normal row produced higher grain yield over the paired row system and other intercrops. This result was also supported by the result of Karim *et al.* (1990) who stated that maximum grain yield of maize was obtained from monoculture in uniform row.

4.1.6 Stover yield

The stover yield was statistically different due to different treatments (Table 1). The highest stover yield was recorded in treatment, T_1 (5595 kg ha^{-1}). T_5 produced second maximum yield (5228 kg ha^{-1}) and followed by T_2 (5218 kg ha^{-1}). In contrast, the lowest stover yield was recorded in treatment, T_4 (4577 kg ha^{-1}). Results revealed that sole crop produced more stover than the paired row system and other intercrop which were supported by the result of Quayyum *et al.* (1987).

4.1.7 Harvest index (HI)

Harvest index differed significantly among the different treatments (Table 1). Treatment, T_1 recorded significantly the highest harvest index (44.61%) followed by T_2 (44.50%) and T_3 (43.76%). T_6 recorded significantly the lowest harvest index (39.52%). From this present study, it appears that sole maize tilizer maintained higher harvest index which was in full agreement with the result of Chui and Shibles (1984).

4.2 Crop characters of chickpea

4.2.1 Plant height

Plant height varied significantly among the treatments (Table 2). The tallest (60.0 cm) plant was recorded in treatment T_3 (MNR + 2 chickpea row with 120 kg N/ha) followed by 59.0 cm with treatment T_5 (MPR + 5 chickpea rows with 120 kg N/ha). The shortest (49.7 cm) plant was recorded in treatment T_7 (sole chickpea with 20 kg N/ha). From the above results, it appears that the higher plant height was recorded in intercrop with the higher dose of N fertilizer than the sole chickpea.

4.2.2 Number of pods plant^{-1}

Pods plant^{-1}, the most important yield attribute, was significantly varied among the treatments (Table 2). Treatment T_7 produced the highest number of pods plant^{-1} (25.7). On the other hand, treatment T_4 produced the lowest number of pods plant^{-1} (18.0) and was followed by T_6 (18.7). This result revealed that sole chickpea with the lower dose of N fertilizer had higher number of pods plant^{-1} than the intercrop even with higher dose of nitrogen. Similar result was obtained from the study of Jahansooz *et al.* (2007).

4.2.3 Number of branches plant^{-1}

Number of branches plant^{-1} was significantly different among the treatments due to the influence of sowing patterns and different nitrogen levels (Table 2). Treatment T_6 produced the highest number of branches plant^{-1} (15.3) and followed by T_7 (14.0). In contrast, treatment T_3 produced the lowest number of branches plant^{-1} (10.7) and followed by T_4 (11.7). This result revealed that as plant had no competition, so lower number of branches plant^{-1} was produced in sole chickpea as plant had experienced no competition. The highest number of branches per plant was found in sole crop which was supported by the result of Banik *et al.* (2006).

4.2.4 Number of seeds pod^{-1}

Number of seeds pod^{-1} significantly varied among the treatments due to various sowing pattern and N levels (Table 2). Treatment, T_5 produced the highest number of seeds pod^{-1} (2.3) followed by T_6 and T_7 (2.0). On the other hand, treatment T_4 produced the lowest number of seeds pod^{-1} (1.3) and followed by T_3 (1.7). The above results in respect of number of seeds per pod were supported by the study of Singh *et al.* (2006).

4.2.5 1000-seed weight

The effect of various sowing pattern and different N levels on 1000-seed weight of chickpea under maize-chickpea intercropping system was significant (Table 2). Treatment T_3 showed the highest 1000-seed weight (119.5 g) due to bigger seed. On the other hand, treatment T_6 showed the lowest 1000-seed weight (105.7 g) due to smaller seed and followed by other treatments. From this result, it appears that 1000-seed weight is higher in intercropping chickpea than the sole chickpea with lower dose of N fertilizer which is consistent with the result of Thakur (2003).

4.2.6 Seed yield

Significant different in seed yield was observed among the treatments due to the influence of various sowing pattern and nitrogen levels under maize-chickpea intercropping system (Table 2). Treatment, T_7 produced the highest seed yield (1623 kg ha^{-1}).The second maximum seed yield (1340 kg ha^{-1}) was obtained by T_5. On the other hand, T_4 produced the lowest seed yield (1085 kg ha^{-1}) which is about 49.6% lower than that of T_7. Similar seed yield was produced by T_3 (1173 kg ha^{-1}) and T_6 (1125 kg ha^{-1}). From this result, it was observed that sole chickpea with the lower dose of N fertilizer had remarkable effect on seed yield and resulted with the highest yield of seed among the treatments under study. The result obtained from the experiment conducted by Thakur (2003) in respect of seed yield of chickpea was supported the present study.

Table 2: Influence of sowing pattern and different nitrogen levels on the plant characters of chickpea as a sole and intercropped with maize

Treatments	Plant height (cm)	No. of pods plant^{-1}	No. of branches Plant^{-1}	No. of seeds Pod^{-1}	1000-seed wt. (g)	Yield(Kg ha^{-1})		HI (%)
						Grain	Stover	
T_3	60.0	22.3	10.7	1.7	119.5	1173	2149	35.3
T_4	56.0	18.0	11.7	1.3	110.0	1085	2342	31.6
T_5	59.0	24.0	12.3	2.3	111.9	1340	2313	36.7
T_6	52.33	18.7	15.3	2.0	105.7	1125	2284	33.0
T_7	49.7	25.7	14.0	2.0	109.8	1623	2505	39.3
$LSD_{(0.05)}$	2.2	1.4	1.5	0.58	6.3	178.4	213.8	1.8
CV (%)	2.1	3.4	6.2	14.5	3.02	4.73	4.90	2.8

Values with common letter (s) within a column do not differ significantly at 5% level of probability

T_3 = MNR + 2 chickpea rows with 120 kg N/ha

T_4 = MNR + 2 chickpea rows with 90 kg N/ha

T_5 = MPR + 5 chickpea rows with 120 kg N/ha

T_6 = MPR + 5 chickpea rows with 90 kg N/ha

T_7 = Sole chickpea with 20 kg N/ha

4.2.7 Stover yield

Stover yield was significantly varied among the treatments (Table 2). The highest stover yield was recorded in treatment, T_7 (2505 kg ha^{-1}) followed by T_4 (2342 kg ha^{-1}) and T_5 (2313 kg ha^{1}). In contrast, the lowest stover yield was recorded in treatment, T_3 (2149 kg ha^{-1}). Results revealed that sole chickpea produced more stover than the intercropping chickpea with various nitrogen levels.

4.2.8 Harvest index (HI)

Harvest index (HI) differed significantly among the treatments (Table 2) in chickpea. Significantly the highest harvest index (39.3%) was recorded in treatment T_7 and the lowest in T_4. From this present study, it appears that sole chickpea with the lower dose of N fertilizer maintained higher harvest index which was in full agreement with the result of Banik *et al.* (2006).

4.3 Evaluation of intercropping system

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 3 & 4 and illustrated under different heads:

4.3.1 Relative yield

In all the intercrop treatments, relative yield of maize was reduced (Table 3). The extent of yield reduction was more observed in intercropping treatments where MNR and MPR maize rows were intercropped with chickpea. However, MPR maize + chickpea planting showed better relative yield of maize than MNR maize + chickpea system. The MPR maize + chickpea system also showed better relative yield of chickpea than MNR maize +

chickpea system. In intercrop treatments, the yield reduction in maize and chickpea might be due to inter and intra plant component competition or antagonistic relationship between maize and chickpea. This result was in conformity with the result of Hashem (1983).

4.3.2 Maize equivalent yield

Higher maize equivalent yields were recorded in all the intercropping treatments than the grain yields recorded in sole maize (Table 3). The highest maize equivalent yield (7664 kg/ha) was recorded from MPR maize intercropped with 5 rows of chickpea with 120 kg N/ha (T_5) followed by (7044 kg/ha) MNR maize intercropped with 2 rows of chickpea with 120 kg N/ha (T_3). Lower nitrogen level for PR or NR intercropped system had lower values of maize equivalent yield which indicates that the growth of maize was reduced due to the shortage of nitrogen in their life cycle. In intercrop situation, the maize equivalent yields were higher due to 2.78 times greater market price of chickpea grain than maize grain price. Similar result also had been reported from maize intercropped with soybean and chickpea by Thakur (2003).

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 3) .Yield advantage was obtained from all the intercropping treatments. Intercropping maize with chickpea at different sowing systems with different N levels gave LER advantages ranging from 37 to 70% with slightly yield loss in maize. Maximum LER (1.70) was obtained from MPR intercropped with 5 rows of chickpea at 120 kg N/ha (T5). The higher LER in intercrop treatments also indicates that the chickpea could inter cropped with maize for higher production and better utilization of resources. This result is also supported by the result of Uddin and Sattar (1993).

4.4 Economical profitability

4.4.1 Gross return

The highest gross return (Tk 137950 ha^{-1}) was in MPR intercropped with 5 rows of chickpea at 120 kg N/ha (T_5) followed by Tk 126796.7 ha^{-1} in MNR maize intercropped with 2 rows of chickpea at 120 kg N/ha (T_3). Both the sole crop of maize was failed to showed higher gross return than intercropped situation. This was due to additional benefit from chickpea. Though chickpea price is higher but gross return is lower in sole situation. Result revealed that intercropping is more profitable than the sole cropping (Table 4). Similar result also had been reported from maize intercropped with soybean and chickpea by Thakur (2003).

4.4.2 Total cost of cultivation

The highest total cost of cultivation (Tk 46532 ha^{-1}) was recorded in treatment T_5 followed by treatment T_3 (Tk 43584 ha^{-1}) (Table 4). The higher cost was involved in treatment T_5 due to paired row of sowing system with more rows of chickpea and higher dose of N fertilizer. The lowest total cost of cultivation (32855 Tk/ha) was required for sole chickpea due to the lower dose of N fertilizer (Table 4).

4.4.3 Net return

The highest net return (Tk 91419 ha^{-1}) was recorded from T_5 though higher cost was involved and was followed by T_3 (Tk 83213 ha^{-1}). The lowest net return (Tk 42342 ha^{-1}) was obtained from sole maize paired row with 120 kg N/ha (T_2) followed by sole chickpea (Tk 48312 ha^{-1}). MPR maize + 5 rows of chickpea at 120 kg N/ha resulted in additional net return of Tk 43033.3

Table 3: Relative yields, maize equivalent yield and land equivalent ratio of different treatments

Treatments	Maize		Chick pea		Maize equivalent yield (kg ha^{-1})	LER
	Grain yield (kg ha^{-1})	Relative yield	Seed yield (kg ha^{-1})	Relative yield		
T_1	4505.7	1.00	---------	-----------	4505.7	1.00
T_2	4191.7	1.00	---------	-----------	4191.7	1.00
T_3	3785.0	0.84	1173.3	0.72	7044.3	1.56
T_4	3163.3	0.70	1085.0	0.67	6177.2	1.37
T_5	3941.7	0.87	1340.0	0.83	7663.9	1.70
T_6	3113.3	0.69	1125.0	0.69	6238.3	1.38
T_7	---------	-----------	1623.3	1.0	4508.3	1.00

T_1 = Sole maize normal row (MNR) with 120 kg N/ha

T_2 = Sole maize paired row (MPR) with 120 kg N/ha

T_3 = MNR + 2 chickpea rows with 120 kg N/ha

T_4 = MNR + 2 chickpea rows with 90 kg N/ha

T_5 = MPR + 5 chickpea rows with 120 kg N/ha

T_6 = MPR + 5 chickpea rows with 90 kg N/ha

T_7 = Sole chickpea with 20 kg N/ha

over corresponding MNR cultivation. On the other hand, if maize and chickpea were cultivated individually in two hectares, the additional net return from their intercrop in one hectare was Tk 43070 ha^{-1}. So, from monetary point of view, the T_5 was the best row management of maize-chickpea intercropping system. All the intercropping systems showed higher net return than sole maize or sole chickpea with uniform or paired row system (Table 4). Similar result also had been reported from maize intercropped with soybean and chickpea by Thakur (2003).

Table 4: Cost and return analyses of different treatments

Treatments	Grain yield (kg/ha)		Gross return (Tk ha^{-1})			Total cost of cultivation (Tk ha^{-1})	Net return (Tk ha^{-1})	BCR
	Maize	Chickpea	Maize	Chickpea	Total			
	(1)	(2)	(3)	(4)	5 = (3+4)	(6)	7 = (5-6)	8 = 5/6
T_1	4506	------	81102.01	-----	81102.01	32716.8	48385.2	2.48
T_2	4192	------	75450.01	------	75450.01	33108.1	42341.9	2.28
T_3	3785	1173	68130.00	58666.70	126796.60	43583.8	83212.9	2.90
T_4	3163	1085	56939.99	54250.00	111189.99	41803.6	69386.4	2.66
T_5	3942	1340	70950.01	67000.00	137950.01	46531.5	91418.5	2.96
T_6	3113	1125	56039.99	56250.00	112289.99	42260.4	70029.6	2.65
T_7	-------	1623	------	81166.60	81166.60	32854.9	48311.7	2.47

T_1 = Sole maize normal row (MNR) with 120 kg N/ha

T_2 = Sole maize paired row (MPR) with 120 kg N/ha

T_3 = MNR + 2 chick pea rows with 120 kg N/ha

T_4 = MNR + 2 chick pea rows with 90 kg N/ha

T_5 = MPR + 5 chick pea rows with 120 kg N/ha

T_6 = MPR + 5 chick pea rows with 90 kg N/ha

T_7 = Sole chick pea with 20 kg N/ha

Market prices:

Maize = 18 Tk/kg

Chick pea = 50 Tk/kg

Labour cost @ Tk 70 day^{-1}

4.4.4 Benefit cost ratio (BCR)

The highest BCR (2.96) was obtained from T_5 followed by T_3 (2.9). In contrast, the lowest (2.28) BCR was obtained from T_2. The result showed that the higher BCR was obtained from intercropping maize and chickpea with NR or PR planting system at 120 or 90 kg N/ha than the sole maize or sole chickpea (Table 4). The result obtained from the present study is consistent with the result of Khaleque *et al.* (1990).

Chapter 5
SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

An experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka during the period from December, 2007 to May, 2008 to study the influence of sowing pattern and nitrogen levels on the productivity under maize-chickpea intercropping system. The experiment was conducted in a Randomized Complete Block Design (RCBD) with 3 replications. The experiment comprised of seven treatments viz, T_1 = Sole maize normal row (MNR) with 120 kg N ha^{-1}, T_2 = Sole maize paired row (MPR) with 120 kg N/ha, T_3 = MNR + 2 chickpea rows with 120 kg N ha^{-1}, T_4 = MNR + 2 chickpea rows with 90 kg N/ha, T_5 = MPR + 5 chickpea rows with 120 kg N/ha, T_6 = MPR + 5 chickpea rows with 90 kg N/ha and T_7 = Sole chickpea with 20 kg N/ha. The collected data were statistically analyzed and the means were adjudged by LSD at 5% level of significance.

Maize and chickpea seeds were sown in line on 10 December, 2007. In all the treatments, the recommended plant population of maize (55,555 plants per hectare) was maintained and in sole chickpea crop plant population was 333,333 plants per hectare. The varieties of maize and chickpea used were Barnali and BARI chickpea-5, respectively. Maize plants received a uniform application of 65, 50, 18, 1 kg/ha of P_2O_5, K_2O, S and B as TSP, MP, Gypsum, and Borax, respectively. Maize under paired row and normal row system was given 120 kg N ha^{-1} and intercrop system as 120 kg N ha^{-1} and 90 kg N ha^{-1} with the view of treatment variables. Sole chickpea received 20 kg nitrogen per hectare. An observation at harvest was made on plant height, yield and yield contributing characters in each treatment.

The effect of sowing pattern and nitrogen levels on yield and yield attributes, such as plant height, cob length, number of pods and branches per plant, seeds per pod, number of grains per cob, 1000-grain weight, grain yield, stover yield and HI were significant. The result revealed that tallest plant was recorded in T_1 in the case of maize and in T_3 for chickpea whereas shortest plant was found in T_6 and T_7 in maize and chickpea, respectively. In maize, longest cob, maximum number of grains per cob, maximum stover yield, and higher harvest index were recorded in T_1 treatment,. In chickpea, the maximum number of pods per plant, the highest number of branches per plant, maximum stover yield, and higher harvest index were observed in T_7. The highest 1000-grain weight was recorded in T_3 for both maize and chickpea.

Results of the experiment revealed that the grain yield of maize significantly affected by different treatments. Higher maize yield was obtained in T_1 (4506 kg ha^{-1}) where maize was grown as sole with 120 kg N/ha under NR system and followed by T_2 (4192 kg ha^{-1}) where maize was grown as a paired row crop with 120 kg N/ha. In intercrop situation, maximum grain yield was obtained in T_5 and the lowest in T_6. Grain yield of maize was significantly affected by higher rate of nitrogen both in PR and NR planting methods. The yield difference was mainly due to variation in number of grains per cob and also cob length. Seed yield of chickpea was also significantly varied due to different treatments. The highest seed yield (1623 kg/ha) was obtained from the sole chickpea (T_7) with lower dose of nitrogen fertilizer. Among the intercropped situation, the highest seed yield was obtained from T_5 and the lowest from T_4. The differences in yield of chickpea in sole and intercrop situations were mainly due to variation in plant population, the number of pods per plant, number of grains per pod etc. Among the yield components of chickpea, pods per plant and number of grains per pod were found responsible for variation of yield.

The intercropping systems were evaluated on the basis of relative yield, maize equivalent yield, land equivalent ratio (LER), net monetary returns per hectare and benefit cost ratio (BCR). Relative yield of maize and chickpea showed that both the component crops in intercropped situation have slight adverse effect compared to sole crop their individual yield but their combined yield was higher. LER varied from 37 to 70% in the different treatments. The highest LER (1.70) was found in T_5 and the lowest in T_4 (1.37) in intercropped situations. Maximum maize equivalent yield (7664 kg/ha) was observed in T_5 and minimum (6177 kg/ha) in T_4 in intercropped situations. Economic analysis of the different treatments showed that the highest gross return (Tk 137950 ha^{-1}), net return (Tk 91419 ha^{-1}) and BCR (2.96) were found in T_5. The results of the study showed that all intercrop treatments gave higher maize equivalent yield than the sole maize. By intercropping maize + 5 rows of chickpea in PR planting method at 120 kg N/ha gave comparatively higher net monetary return compared to that obtained from monoculture of maize and chickpea. As a result, the cultivation of maize and chickpea in PR planting system with higher dose of N under intercropping situation would be profitable due to higher yield. So, T_5 (MPR + 5 rows of chickpea with 120 kg N/ha) may be recommended as maize-chickpea intercropping system although it needs more trials under farmer's field conditions at different agro-ecological zones of Bangladesh. Finally the results lead to the conclusion that,

I) all the intercropping treatments had better performance in respect of productivity over sole crop under maize-chickpea intercropping system and

II) intercropping maize + five chickpea rows in paired row (PR) planting methods at higher N dose could be viable from economic point of view (i.e., maize equivalent yield, LER, relative yield, gross return, net return, BCR etc).

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APPENDICES

Appendix I: Physiochemical properties of the soil prior to seed sowing

Characteristics	Value	Interpretation	Critical value
% sand	26	…….	…….
% silt	45	……..	…….
% clay	29	…….	…….
Textural class	…..	Silty-clay	…….
pH	5.6	Slightly acidic	…….
Organic carbon (%)	0.45	…….	…….
Organic matter (%)	0.78	Very low	…….
Total N (%)	0.03	Very low	0.12
Available P	20.00	…….	7.0
Exchangeable K (me/100 g soil)	0.10	Low	0.12
Available S (ppm)	45	Very high	10.0

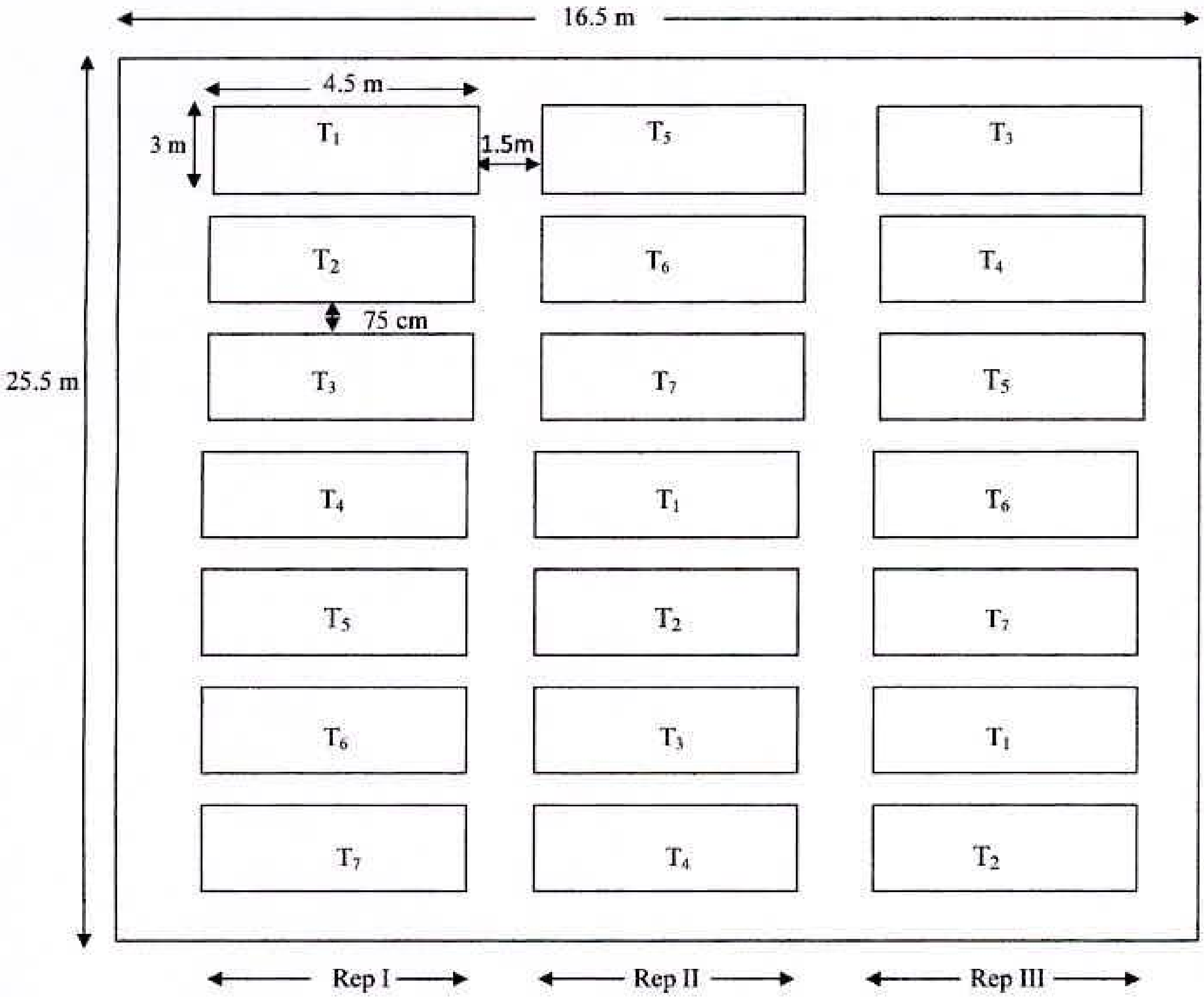
Source: Soil Resources Development Institute (SRDI), Dhaka-1207 and Fertilizer Recommendation Guide 2005, BARC.

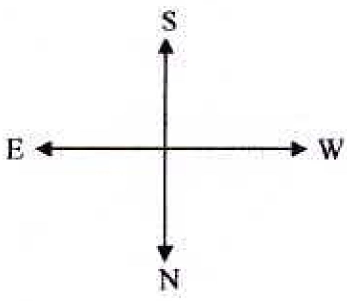
Appendix II: Monthly average air temperature, relative humidity and total rainfall of the experimental site during the period from December, 2007 to May, 2008.

Month	Relative humidity (%)	Temperature (°C)			Rainfall (mm)
		Maximum	Minimum	Mean	
December	69.5	29.5	13.6	24.0	3.0
January	70.6	26.9	16.2	21.5	00
February	68.5	24.5	18.2	19.2	4.0
March	61.0	28.9	18.9	23.4	3.0
April	62.5	29.5	20.3	24.9	3.0
May	62.1	29.6	21.5	25.5	3.5

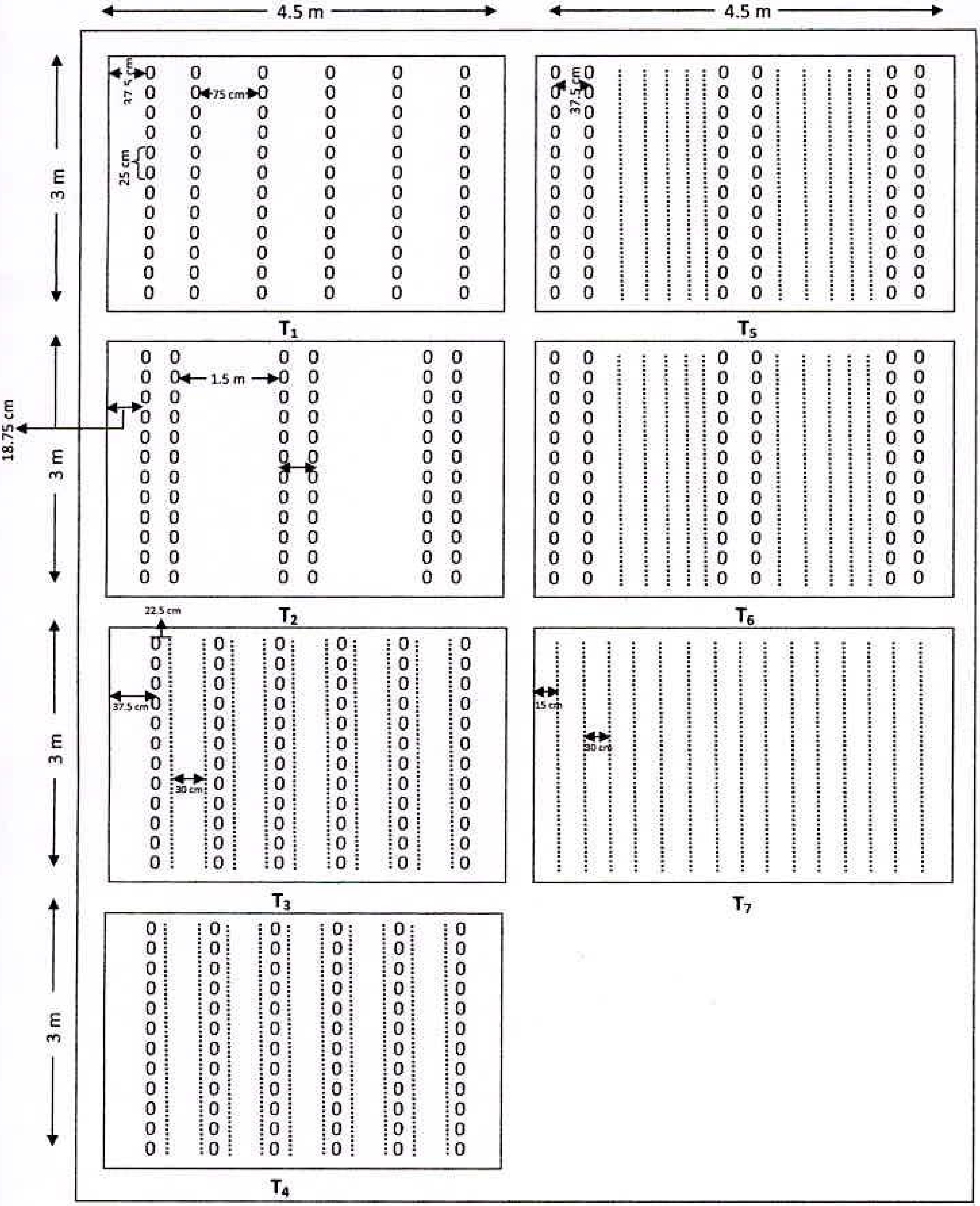
Source: Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka-1212.

Appendix III: Layout of experimental field





Appendix IV. Layout of treatments arrangements



000 = Maize row

...... = Chickpea

Appendix V: Summary of analysis of variance (mean square) for different characters of maize

Source of variance	Degree of freedom	Mean sum squares						
		Plant height (cm)	Cob length (cm)	No. of grains/cob	1000-grain wt. (g)	Grain yield (kg/ha)	Stover yield (kg/ha)	HI (%)
Treatment	5	279.4**	9.1**	3312.1**	2257.6**	928127.2**	418264.7**	13.03**
Replication	2	3.2	1.1	44.2	283.8	2256.9	1862.7	0.06
Error	10	1.5	0.589	16.8	167.2	5045.6	3754.4	0.31

** Significant at 1% level of probability

Appendix VI: Summary of analysis of variance (mean square) for different characters of chickpea

Source of variance	Degree of freedom	Mean sum squares							
		Plant height (cm)	No. of pods/plant	No. of grains/plant	No. of seeds/pod	1000-seed wt. (g)	Seed yield (kg/ha)	Stover yield (kg/ha	HI (%)
Treatment	4	57.6**	33.2**	10.43**	0.52*	76.4*	145752.5**	48954.2*	31.2**
Replication	2	4.2	0.87	1.80	0.15	7.99	4041.7	2195.8	0.27
Error	8	1.4	0.53	0.63	0.1	11.3	3600.00	12889.8	0.93

** Significant at 1% level of probability
*Significant at 5% level of probability