EFFECT OF INTERCROPPING CHICKPEA WITH SUNFLOWER UNDER DIFFERENT ROW AND SPACING ARRANGEMENTS

BY

SHAMA NASRIN

REG. NO. : 04-01499

A Thesis
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 (MS)
IN
AGRONOMY

SEMESTER: JULY-DECEMBER, 2009

APPROVED BY:

Prof. Dr. Md. Jafar Ullah
Supervisor
Department of Agronomy
SAU, Dhaka

Prof. Dr. Md. Hazrat Ali
Co-Supervisor
Department of Agronomy
SAU, Dhaka

Prof. Dr. Md. Fazlul Karim
Chairman
Examination Committee

DEDICATED
TO
MY BELOVED PARENTS

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

Memo No: SAU/Agronomy/

CERTIFICATE

This is to certify that the thesis entitled "**Effect of Intercropping Chickpea with Sunflower under Different Row and Spacing Arrangements**" 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 carried out by **Shama Nasrin**, Registration number: **04-01499** 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, received during the course of this investigation has duly been acknowledged.

Dated: 11-05-2011

Dhaka, Bangladesh

Prof. Dr. Md. Jafar Ullah

Department of Agronomy

Sher-e-Bangla Agricultural University

Dhaka-1207

ACKNOWLEDGEMENTS

All praises are due to the Almighty Allah, the Supreme Ruler of the universe Who enables the author to complete this present piece of work.

The author feels proud to express her heartiest sense of gratitude, sincere appreciation and immense indebtedness to her supervisor Dr. Md. Jafar Ullah, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Dhaka, for his continuous intellectual and scholastic guidance, assistance, constructive criticism and suggestions in carrying out the research work and preparation of the thesis, without his intense co-operation this work would not have been possible.

The author also expresses her gratefulness and best regards to respected Co-Supervisor Dr. Md. Hazrat Ali, Professor, Department of Agronomy, SAU, Dhaka, for his scholastic guidance, constructive criticism and valuable suggestions during the entire period of course and research work and preparation of this thesis.

It is also a great pleasure for the author to express her sincere and deep sense of gratitude to Dr. Md. Fazlul Karim, Professor and Chairman, Department of Agronomy, SAU, Dhaka for his encouragement and co-operation and for providing all the necessary facilities during entire period of this program.

The author expresses her gratitude and indebtedness to all the honorable course instructors of Department of Agronomy, SAU, Dhaka for their kind help and co-operation in various stages towards completion of this research work.

The author expresses her sincere appreciation to her brother, sisters, relatives, well wishers and friends for their inspiration, help and encouragement throughout the study.

The Author

EFFECT OF INTERCROPPING CHICKPEA WITH SUNFLOWER UNDER DIFFERENT ROW AND SPACING ARRANGEMENTS

ABSTRACT

The experiment was conducted to find out the effect of intercropping chickpea with sunflower under different row and spacing arrangements at the experimental field of Agronomy Department of Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from November 2008 to March 2009. Seeds of sunflower variety DS-1 (Kironi) and Chickpea variety BARI-Chola-5 used as a test crop for the study. The experiment consisted of nine row arrangement combinations of sunflower and chickpea plus sole treatment of both the crops. The row arrangement of sunflower were recommended as 50 cm apart, paired rows 30 cm apart followed by 70 cm gap; and paired rows 30 cm apart followed by 100 cm gap. Within these were three row arrangements, 1-4 rows of chickpea at different spacing which altogether made nine treatment combinations. Results revealed that soil moisture, light intensity, growth parameters, yield attributes and yield, land equivalent ratio, soil pH and N, P, K had significant differences. The maximum soil moisture (30.11-35.20%) was recorded when two rows of chickpea were sown 40 cm apart in 70 cm gap of sunflower paired rows, while the minimum (25.10-27.60%) in the sole sunflower plots. The highest LER (1.76) was recorded from T_5 and the lowest LER from the sole crop both sunflower and chickpea. The highest equivalent yield (EY) of sunflower (3.81 t ha^{-1}) was recorded from T_5 and the lowest (2.09 t ha^{-1}) from the sole crop of chickpea. The highest EY of chickpea (4.39 t ha^{-1}) was recorded from T_5 and the lowest (2.57 t ha^{-1}) from the sole crop of sunflower. The highest combined yield of sunflower and chickpea (4.08 t ha^{-1}) was recorded from T_5 and the lowest (2.23 t ha^{-1}) from the sole crop of sunflower. The highest benefit cost ratio (3.52) was recorded from T_5 and the lowest (1.49) from the sole crop of chickpea.

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CHAPTER 1

INTRODUCTION

Bangladesh is an agro based country with total area of 147,570 square kilometer, 13.7 million hectares of crop land and cropping intensity of 175.97 percent. About 21.20 percent of the Gross Domestic Product (GDP) comes from agriculture sector (BBS, 2008). Every year the country is badly affected by the adverse environmental disasters, such as low rainfall, drought, extreme temperature, flood, tornado and other natural hazards. The land area of this country is very limited compared to it's population about 14.46 crore. So, increasing agricultural production per unit area of land is becoming most important step to cope with the present population growth (1.06%) in Bangladesh (BBS, 2008). In recent years multiple cropping has been gaining importance as a means of more crop production in limited land area particularly in the countries with small farm holdings coupled with higher population density.

Intercropping is an age old practice and it has been recognized as a very common practice throughout the developing tropics (Willey, 1979). It is considered as the practical application of ecological principles such as diversity, crop interaction and other natural regulation mechanisms. Intercropping is defined as the growth of two or more crops in proximity in the same field during a growing season to promote interaction between them. Available growth resources, such as light, water and nutrients are more efficiently absorbed and converted to crop biomass by the intercrop as a result of differences in competitive ability for growth factors between intercrop components. The more efficient utilization of growth resources leads to yield advantages and increased stability compared to sole cropping (Altieri, 1991). Under the general category of intercropping there are four subcategories: mixed, row, strip and relay intercropping. The degree of spatial and temporal overlap in the two crops can vary to some extent, but both requirements must be met for a cropping system to be an intercrop. Numerous types of intercropping, all of which vary the temporal and spatial mixture to some degree, have been identified (Andrews and Kassam, 1976).

Intercropping offers farmers opportunity to engage nature's principle of diversity on their farms. Spatial arrangements of plants, planting rates, and maturity dates must be considered when planning intercrops. Intercrops can be more productive than growing pure stands. Many different intercrop systems are discussed, including mixed intercropping, strip cropping, and traditional intercropping arrangements. Pest management benefits can also be realized from intercropping due to increased diversity. Harvesting options for intercrops include hand harvest, machine harvest for on-farm feed, and animal harvest of the standing crop (Preston, 2003).

Intercropping is an excellent crop production technique. It increases total production and reduces chemical use, the risk of total crop failure and stabilizes yield. Intercropping is proved to be an excellent production system to increase total yield, higher monetary return and greater resource utilization and fulfill the diversified need of the farmers (Singh, 1986). Intercropping is also considered as a well recognized practice for better land use system along with substantial yield advantages compared to sole cropping. These advantages may be especially important because they are achieved not by means of costly inputs but also by the simple expedient of growing crops together (Willey, 1979).

In recent years, many scientists are engaged to improve intercropping system for long time to achieve higher yield benefit. Among different cropping systems, intercropping system was found to be a better practice for increased growth, yield and development. In Bangladesh, pulse crops are generally grown without fertilizer or manure. However, it was found that the yield of pulse could be increased substantially by using fertilizers. Pulses, although fix nitrogen from atmosphere, it was also evident that nitrogen application became helpful to increase the yield (Ardesana *et al.*, 1993). Intercropping with leguminous crops is beneficial as it helps to improve the soil fertility consequently it increase the productivity. Generally legumes in association with non-legumes not only helps to utilize the nitrogen being fixed in the current growing season, but also keeps residual nutrient build up of the soil (Sharma and Choubey, 1991).

Sunflower (*Helianthus annuus* L.) is one of the few crop species that originated in North America. It was probably a "Camp follower" of several of the western native American tribes who domesticated the crop (possibly 1000 BC) and then carried it eastward and southward of North America. Production in these regions in the 1980s has declined mostly because of low prices, but also due to disease, insect and bird problems. Sunflower acreage is now moving westward into dryer regions; however, 85% of the North American sunflower seed is still produced in North and South Dakota and Minnesota (Oplinger, *et al*., 1990).

Chickpea (*Cicer arietinum* L.) is one of the important pulse crops in Bangladesh as well as in the world. In Bangladesh, about 85% of the chickpea crop is grown in the five greater districts of Faridpur, Jessore, Kustia, Rajshahi and Pabna. It is generally grown under rain-fed or residual soil moisture conditions in rabi season. Among the major pulses grown in Bangladesh, chickpea ranked fifth in area and production but second in consumption priority. It covers an area of 16,446 ha producing 11,980 tons of yield with national average of 748 kg ha^{-1} (BBS, 2008).

Practicing intercropping of sunflower with chickpea, farmers can obtain sunflower and pulse at the same time from the same land. Higher land equivalent ratio (LER) values are obtained with intercropping (Sarno *et al*., 1998). Insurance against total crop failure under aberrant weather conditions or pest epidemics are the most important advantages of intercropping system (Dey and Singh, 1981). It was known that intercropping legumes in sunflower increased soil cover, reduced soil erosion and increased soil carbon and nitrogen (Kandel *et al*., 1997). Considering the present context the study was designed with the following objectives:

1. Study the effect of row arrangements of sunflower and chickpea on yield and yield contributing characters for both the crops.

2. Examine the productivity performance of intercropping of chickpea with sunflower.

CHAPTER 2

REVIEW OF LITERATURE

Intercropping is defined as the growth of two or more crops in proximity in the same field during a growing season to promote positive interaction between them. Among different cropping systems, intercropping system was found to be a better practice for increased growth, yield and development. Insurance against total crop failure under unusual weather conditions or pest epidemics are the most important advantages of intercropping system. But very few research works related to intercropping have so far been carried out in Bangladesh. However, some important and informative works those have so far been done both at home and abroad, have been reviewed in this chapter as follows-

Field experiments were conducted by Tripathi and Lawande (2008) in Pune, Maharashtra, India, from 2001 to 2003, to evaluate the performance of different intercrops, i.e. onion, garlic, potato and cabbage, with sugarcane in 4 different planting and irrigation systems. The highest yield of sugarcane was recorded in pair row planting with sprinkler irrigation. Among the various intercrops, the highest yield of sugarcane was recorded when intercropped with garlic, followed by potato, cabbage and onion. The highest water saving was recorded in the sugarcane-potato combination under drip irrigation system. The highest net profit was obtained with sugarcane-cabbage combination under sprinkler irrigation. The sugarcane-cabbage and sugarcane-onion combinations in pair-row planting with sprinkler irrigation were the best combinations in terms of yield. The yield of garlic was lower under cropping than the average yield level of sole garlic. This was because of late planting of garlic to match with the planting of sugarcane. But if the water savings was considered, the sugarcane-cabbage and sugarcane-onion combinations in pair row planting and drip irrigation were the best combinations.

Ylmaz *et al.* (2008) carried out an experiment with alternate planting combinations of maize (*Zea mays*) with common bean (*Phaseolus vulgaris*) or cowpea (*Vigna sinensis* [*V. unguiculata*]) were compared with the solitary planting of each crop during 2003 and 2004 in Turkey. The treatments consisted of sole planting of maize (71,500 plants ha^{-1}), common bean (285,750 plants ha^{-1}) and cowpea (285,750 plants ha^{-1}), and 6 maize-legume intercropping series (50:50, 67:50 and 100:50% proportions with one- or 2-row planting patterns). The planting patterns were evaluated based on several intercropping indices, such as land equivalent ratio, relative crowding coefficient, actual yield loss, monetary advantage index, and intercropping index. Compared to solitary planting, the maize-cowpea and maize-common bean intercropping systems at a 67:50% proportion (plant density) was superior in terms of yield, land use efficiency and economics, regardless of the planting pattern.

A field experiment was conducted by Xiao *et al.* (2008) to establish optimal intercropping configuration pattern for *Cumunum cyminum* L. and maize (*Zea mays* L.) in the Hexi corridor. The result shows that the four patterns had different effects on plant height, root activity, photosynthetic rate, chlorophyll content as well as yield of *Cumunum cyminum* and *Z. mays*, respectively. *Cumunum cyminum* density was 120000 plants ha^{-1} and *Z. mays* density was 52,500-60,000 plants ha^{-1} at 20 cm plant spacing and 85-95 cm row spacing, were the best intercropping patterns. *Cumunum cyminum* and *Z. mays* under study grew harmoniously with reasonable population structure, good ventilation and light transmission, resulting in robust growth, good agronomic feature and ultimately high yield.

Govind and Ravi (2007) carried out a field experiment during three consecutive rabi seasons from 2001 to 2004 at Dholi on intercropping of chickpea and mustard to find out appropriate spatial row arrangement of component crops for yield potential, land utilization and comparative economic return under different dates of planting. The highest chickpea equivalent yield, net income and mean B:C ratio were obtained when crops were planted on October 20 which gradually decreased due to delayed planting up to November 20, although, the land equivalent ratio and competitive index were favourable for the system under late planting. Among various intercropping systems, the highest chickpea equivalent yield, net income and B : C ratios were obtained at 6:1 row ratio. The competitive index (0.044) was more favourable to same row ratio than other row ratios of chickpea and mustard.

A field experiment was conducted by Marer *et al.* (2007) during kharif season of 2004 at Main Agricultural Research Station, Dharwad (Karnataka) to study the feasibility and adaptability of intercropping of maize and pigeonpea in 1:1, 2:1, 2:2, 3:1 and 4:2 row proportions with 50 and 100% pigeonpea population levels. Sole crop of maize and pigeonpea recorded significantly higher grain yield (6337 and 1090 kg ha^{-1} respectively). Among intercropping systems, intercropping of maize and pigeonpea at 4:2 row ratio with 50 per cent pigeonpea population resulted in maximum maize equivalent yield (8076 kg ha^{-1}), net returns (Rs. 30492 ha^{-1}) and B:C ratio (2.75) over other intercropping systems and sole crops.

Patel *et al.* (2007) conducted a field experiment in Gujarat, India, during the 2002 wet season to select the best wet season crops for intercropping (1:1 and 1:2 row ratios) with castor bean (*Ricinus communis*)to increase net returns and land equivalent ratio. The highest castor bean seed yield (752 kg ha^{-1}) was obtained in sole crop of castor bean. Intercropping reduced castor bean yield. The maximum reduction (40%) in yield was recorded when castor bean was intercropped with moth bean at 1:1 row ratio, while the minimum reduction on seed yield was recorded when castor bean was intercropped with cowpea at 1:2 row ratio (1.68%). Castor bean + green gram and castor bean + cowpea intercropping increased castor bean equivalent yield compared with castor bean equivalent yields of the sole crops. The highest castor bean equivalent seed yield of 1160 kg ha^{-1} was recorded in castor bean + green gram (1:2). Intercropping of all the crops increased the land equivalent ratio compared with sole crops. The highest land equivalent ratio (48%) was recorded in the castor bean + cowpea (1:2) intercropping. Similarly, the highest net returns (Rs. 15 214 ha^{-1}) was obtained with castor bean + green gram (1:2) intercropping.

Intercropping of sabai grass (*Eulaliopsis binata*) with groundnut or cluster bean (*Cyamopsis tetragonolobus*) was studied by Manisha *et al.* (2007) under four crop geometries in West Bengal, India. Two rows of groundnut or cluster bean with their standard spacing were accommodated after each row of sabai grass with 100% plant population of sabai grass (spacing 100 cm × 50 cm). A strip of 2 m wide was left after every 4 rows of sabai grass to accommodate a few rows of groundnut or cluster bean. A strip of 2 m wide was left after every 3 rows of sabai grass to accommodate a few rows of groundnut or cluster bean with 75% plant population of sabai grass (spacing 100 cm × 50 cm); a strip of 3 m wide was left after every 2 rows of sabai grass (skipping two rows) to accommodate a few rows of groundnut or cluster bean with 50% plant population of sabai grass (spacing: 100 cm × 50 cm) for three years under acid lateritic soil. It was found that dry yield of sabai grass was higher in intercropping under groundnut. Lowest yield of intercropped sabai grass was noted when the crop was in association with cluster bean.

A field experiment was conducted by Tripathi *et al.* (2007) at JNKVV-Zonal Agricultural Research Station, Tikamgarh during rainy seasons of 2003, 2004 and 2005 under rainfed condition. On the basis of three years mean, results revealed that the highest sesame grain equivalent yield, net return and B:C ratio were recorded with sole sesame as compared to sole clusterbean and sole blackgram. In intercropping system, clusterbean at 3:1 row ratio recorded higher sesame grain equivalent yield. The higher net returns and benefit cost ratio were also recorded with clusterbean at 3:1 row ratio intercropped with sesame. The intercropping of sesame + blackgram at 3:1 row ratio will remain in 2nd position in respect of sesame grain equivalent yield, net return & B. C. ratio.

A field experiment was conducted by Srivastava and Verma (2007) during the winter seasons of 1999-2000 and 2000-01 in Uttar Pradesh, India, to evaluate the effect of various row ratios, mustard cultivar and fertilizer rates on the growth, phenological events and yield of component crops in wheat + mustard intercropping. Treatments comprised: 8:1, 5:1 and 2:1 row ratios; Sanjucta Asesh and Vardan mustard cultivars; and 33.33%, 66.67% and 100% recommended dose of NPK (90 : 45 : 45 kg NPK ha^{-1}). Association of wheat with mustard under the 8:1 row ratio recorded the maximum values in terms of leaf area index, dry matter accumulation, biological and grain/seed yields of both crops, but the magnitude of these parameters decreased markedly in the 5:1 ratio, and the minimum was associated with the 2:1 row ratio, whereas harvest index of wheat decreased significantly from 8:1 to 2:1 row ratio. To achieve higher growth and yields of mustard along with efficient resource utilization, application of 100% recommended dose of fertilizer to both the component crops was imperative.

Singh (2007) carried out a field experiment in Kashmir, India, during the rainy (kharif) season of 2002 and 2003, to study the response of sunflower (*Helianthus annuus*), French bean (*Phaseolus vulgaris*) intercropping to different row ratios (1:1 and 2:2) and nitrogen levels (0, 40, 80 and 120 kg ha^{-1}) under rainfed conditions. Intercropping reduced the values of growth parameters, yield attributes and seed yield of both sunflower and French bean compared with their sole crops. Both the intercropping recorded significantly higher sunflower-equivalent yield (SEY), net income and benefit : cost ratio than their sole stands. Intercropping of sunflower + French bean under 2:2 row ratio recorded significantly higher SEY (1231 kg ha^{-1}), land-equivalent ratio (1.25), net income (Rs. 13138 ha^{-1}) and benefit : cost ratio (1.95), and also indicated a modest competitive ratio (2.10 : 0.48), followed by sunflower + French bean in 1:1 ratio. Both sunflower and French bean in sole and intercropping responded favorably up to 80 kg N ha^{-1} only for higher leaf area index, dry matter accumulation, yield attributes, seed yield, N uptake, net income and benefit : cost ratio. The interaction effects of the factors showed that mean SEY responded to N application up to 80 kg ha^{-1} in 2:2 row ratio of sunflower + French bean.

A field experiment was conducted by Dutta and Bandyopadhyay (2007) during the rainy seasons (kharif) of 2002 and 2003 under typical rainfed upland conditions at Jhargram, West Bengal, India, to study the groundnut (*Arachis hypogaea* cv. JL 24) + pigeon pea (*Cajanus cajan* cv. UPAS 120) intercrop management under various plant densities and fertilizer levels. The treatment comprised 2 sole stands of groundnut and pigeon pea and 12 stands of intercropping groundnut and pigeon pea in 4:2 row ratio under different plant density and fertilizer dose. Based on the results of 2 years, the highest pod yield of groundnut (1322 kg ha^{-1}) and pigeon pea (985 kg ha^{-1}) was recorded under their sole treatment. The best performing treatment was groundnut (with 100% plant density and 100% recommended dose of fertilizer) + pigeon pea (with 75% plant density and 50% of recommended fertilizer) intercropping system which gave the highest groundnut-equivalent yield (1410 kg ha^{-1}), net return (Rs. 18418 ha^{-1}), benefit : cost ratio (1.88), land-equivalent ratio (1.18), relative crowding coefficient (2.67) and monetary advantage (Rs. 4301 ha^{-1}).

Ghosh *et al.* (2006) conducted an experiment and reported that inclusion of legumes in the cropping system had been known since times immemorial. Legume was a natural mini-nitrogen manufacturing factory in the field and the farmers by growing these crops can play a vital role in increasing indigenous nitrogen production. Legume helped in solubilizing insoluble P in soil, improving the soil physical environment, increasing soil microbial activity and restoring organic matter and also had smothering effect on weed, increased productivity and nutrient use-efficiency in various systems.

Howlader (2006) reported that highest land equivalent ratio of 1.09 was obtained from the 4:1 row ratio of wheat: bush bean at maturity stage but 1.44 was obtained from the 3:2 row ratio of wheat: bush bean at vegetative stage. He found that highest wheat equivalent yield was 5.095 t ha^{-1} at maturity stage and 4.734 t ha^{-1} at vegetative stage obtained from the 3:2 row ratio of wheat bush bean.

Islam (2006) conducted a study and reported that higher yields of wheat (3.00-3.08 t ha^{-1}) were obtained with wheat 100% + grasspea 20% + fertilizer 100% and wheat 100% + grasspea 100% + fertilizer 120% treatments. Highest fodder yield (1.47 t ha^{-1}) was obtained with the treatment of wheat 100% + grasspea 100% + fertilizer 120%. The best land equivalent ratio (LER), benefit-cost ratio (BCR) and total net return were 1.96, 1.558 and Tk. 14466.50 ha^{-1} respectively and these were obtained with the treatment of wheat 100% + grasspea 100% + fertilizer 120%.

A field experiment was conducted by Ahlawat *et al.* (2005) at New Delhi, India to evaluate the productivity of chickpea (*Cicer arietinum*) based intercropping systems. The yield of chickpea was adversely affected by intercropping with Indian mustard (*Brassica juncea*), barley (*Hordeum vulgare*) and linseed (*Linum usitatissimum*). However, the magnitude of reduction was relatively higher with intercropiing with Indian mustard. Further, the yield of chickpea increased as the proportion of chickpea increased in the mixture from 2:1 to 4:1, whereas the reverse trend was observed in the yield of intercrops. Sole Indian mustard recorded the highest total productivity in terms of chickpea equivalent yield (CEY), followed by chickpea + Indian mustard (2:1), chickpea + linseed in various row proportions and sole chickpea recorded similar CEY, which was markedly lower than sole barley and linseed and chickpea intercropped with Indian mustard and barley in various proportions, except chickpea + barley in 4:1 row proportion. Among various intercropping systems, chickpea + barley, especially in 2:1 and 3:1 row proportions, showed yield advantages in terms of land equivalent ratio (LER), while all the sole intercrops and chickpea-based intercropping systems, except chickpea + linseed (4:1) recorded higher income equivalent ratio over sole chickpea.

An experiment was conducted by Dua *et al.* (2005) at Shimla, Himachal Pradesh, India, during 2001 and 2002 to evaluate different row ratios and cropping geometry in potato (*Solanum tuberosum*) + French bean (*Phaseolus vulgaris*) intercropping system. The potato was a dominant species when it was sown in lesser proportion than French bean, whereas French bean dominated potato in intercropping when its proportion was equal or less than that of potato. All the intercropping treatments showed yield advantage over sole cropping. Based on land-equivalent ratio (1.4975) and compensation ratio, the maximum advantage from the intercropping of potato + French bean was obtained when planted in 2:2 row ratio with 100% population density of each crop.

Thakur *et al.* (2004) conducted a field experiment during 1994-95 and 1995-96 in Chhindwara, Madhya Pradesh, India, to select the most compatible intercrop with sunflower under varying row proportions for increased and economical productivity. The treatments comprised: 50 cm sole sunflower; 25 cm sole chickpea; 25 cm sole pea; 25 cm sole linseed; 25 cm sole niger; sunflower + chickpea (1:1 and 1:2); sunflower + pea (1:1 and 1:2); sunflower + linseed (1:1 and 1:2); sunflower + niger (1:1 and 1:2). Sunflower + chickpea (1:1) gave the maximum plant height (100 cm) of wheat and land equivalent ratio (1.27). Sunflower + linseed (1:1) gave the highest head size (12.5 cm) and grain yield (1525 kg ha^{-1}) of sunflower. Sunflower + niger (1:1) had the highest number of seeds per head (279) and relative crowding coefficient (3.33). Sunflower + pea (1:1) and (1:2) and sunflower + linseed (1:2) gave the highest seed chaffiness (9.2%), sunflower equivalent yield (1101 kg ha^{-1}) and stem girth (5.0 cm), respectively.

An experiment was conducted in Pusa, Bihar, India, during 2001 by Haidar *et al.* (2004) to study the effect of toria (*Brassica campestris* var. toria cv. TS-17) or yellow mustard (*B. campestris* var. sarson cv. Rajendra sarson-I) intercropping, one and sown in two rows, with sugarcane on crop yield. Intercropping of 2 rows of yellow sarson with sugarcane recorded the highest reduction (23.7%) in nematode population followed by sugarcane + one row of yellow mustard at harvest of intercrops. This sequence showed prolonged effect of toxicity as evidenced by 12% reduction in nematode population from initial density level at the time of harvest of sugarcane. Sugarcane + yellow mustard intercropping system exhibited the highest cane equivalent yield.

Abdur *et al.* (2004) conducted an experiment in Pakistan during 1999 and 2000 to study the effect of legume intercropping on the growth of sorghum. The treatments comprised single row (60 cm apart), double row (30/90 cm) and triple row strip (30/120 cm) planting of sorghum (cv. PARC-SS-II), with and without mungbean (cv. MN-92) and guar (cv. DK-3). The planting pattern had a significant effect on the maturity of sorghum during 1999. The double row strips took maximum number of days (104.4) to maturity. The interaction between planting patterns and legume intercropping with regards to maturity of sorghum was not significant in both years. Legume intercropping significantly decreased the number of grains per panicle compared to sole sorghum. Sole sorghum produced the maximum number of grains per panicle compared to sorghum grown in association with mungbean and guar. The interaction between planting pattern and legume intercropping was also not significant. Sorghum grain yield was significantly affected by planting pattern in both years where the highest yield was obtained from double row strips. Legume intercropping also significantly affected sorghum grain yield.

Mengping and Zhangjinsong (2004) observed that the intercropping system was an established fact that the system increased water utilization efficiency, shows higher land equivalent ratio and above all gives higher yield.

Nargis *et al.* (2004) evaluated an experiment on mixed cropping of lentil (100%) and wheat (20, 40, 60 or 80%). It was observed that in lentil, 100% lentil + 40% wheat gave the highest number of branches per plant (3.25), whereas 100% lentil + 60% wheat recorded the greatest plant height (35.70 cm). The highest number of seeds per plant (47) and seed yield (1278 kg ha^{-1}) of lentil were obtained under line sowing. Sole wheat (broadcast) produced the tallest plants (89.15 cm) and the longest spikes (9.84 cm). The highest land equivalent ratio (1.52), monetary advantage (63%) and benefit-cost ratio (1.84) were recorded for intercropping lentil (100%) and wheat (40%).

Cheng *et al.* (2003) reported that when higher nitrogen was applied under wheat + blackgram intercropping system, 1000-seed weight was greater than mono cropped wheat.

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

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

A field investigation was carried out by Chakravorty and Mrinalinee (2002) during summer season 1998, to evaluate the yield and economics of intercropping maize cv. Vijoy with pulses (green gram cv. ML 56, black gram cv. T-9) and cowpea cv. Local under rainfed conditions in Jorhat, Assam, India. Among intercropping system, paired rows of maize and black gram proved superior to all other treatments with respect to growth and yield attributing characters, grain yield of maize (26.89 q ha^{-1}) and grain yield of black gram (3.82 q ha^{-1}). Paired rows of maize and cowpea found to be the best with respect to maize equivalent yield (45.03 q ha^{-1}) net return (Rs. 14,952) and monetary advantage (Rs. 5380.77). Between 2 methods of planting, paired row planting was found to be better than alternate row planting in respect to yield attributing characters, yield, maize equivalent yield and economic indices.

Ghanbari *et al.* (2002) reported that significant effect on spike length of wheat was found with intercropping system. They reported that proper fertilization under intercropping system increased spike length of wheat.

Ashok *et al.* (2001) evaluated an experiment at New Delhi. They found that number of tillers per plant of wheat was not significantly affected by wheat based intercropping system.

Oleksy and Szmigiel (2001) reported that mixed or intercropping has been reported to have many advantages for the farmers. It increased the total production; acted as insurance against failure of the principal crop and better utilization of inter space in crops. It also reduced the cost of intercultural operation and increased the fertility of the soil.

Qiujie *et al.* (1999) conducted an experiment where wheat and groundnuts were relay cropped or sequentially cropped and given 2 rates each of N and P fertilizer, alone or in combination. Average wheat and groundnut yields were increased by 27.7 and 14.3%, respectively, compared with sequential cropping. Both individual and combined applications of N and P significantly increased yield, and yield stability was greatest with combined application in the relay intercropping system.

Rahman (1999) reported that intercropping of grasspea with wheat was sustainable over sole crop.

Ahmad *et al.* (1998) conducted a field experiment in Pakistan. Wheat and lentil were grown alone or intercropped in 80 cm × 100 cm strips at wheat : lentil row ratios of 4:3, 5:3, 8:3 or 10:3. Wheat grain yield was highest (4040 kg ha^{-1}) with the 10:3 row ratio. This treatment produced lentil seed yield of 424 kg ha^{-1}. The 8:3 row ratio produced wheat grain yield of 3760 kg and lentil seed yield of 481 kg and the highest net return, which was only slightly higher than the returns obtained with the 10:3 row ratio.

Dwivedi *et al.* (1998) found that all intercropping systems had higher total yield and net returns than pure stands.

Malik *et al.* (1998) conducted a field trial with wheat grown alone or intercropped with lentils, gram or rape. Grain yield of wheat was decreased by 371, 420 and

388 kg ha^{-1} with intercropping of lentil, gram and rape respectively. However, losses in wheat yield were compensated by increased income from the intercrops. The highest net income with a benefit-cost ratio (BCR) of 2.75 was obtained from wheat-lentil intercropping compared with a BCR of 2.35 for wheat alone.

Sarma *et al.* (1998) conducted a field study in rabi season (winter). Wheat, lentils and peas were grown alone or intercropped as 1:1 or 2:2 rows between wheat and each of the other crops. Wheat yield was 3.0 - 3.1 t ha^{-1} when grown alone and 2.6 - 20.8 t ha^{-1} when intercropped. Wheat-equivalent yield was highest from sole Rajmash, because of the higher economic value of this crop. Wheat-equivalent yield was higher in intercropping systems than in sole wheat, with the best results given by intercropping with Rajmash.

Sarno *et al.* (1998) reported that higher equivalent yields were obtained with intercropping treatment of wheat-field pea. The land equivalent ratio (LER) values were found to be greater.

Nazir *et al.* (1997) reported that biological efficiency (yield) and economics of wheat-based intercropping were introduced as the intercropping systems of wheat + fenugreek, wheat + lentils, wheat + chickpeas, wheat + linseed, wheat + barley and sole crop wheat in Pakistan. In monetary terms, both the wheat-fenugreek and wheat-lentil intercropping systems proved to be more beneficial than the other cropping systems, including mono cropped wheat. They also reported that all the intercropping systems gave substantially higher total yield equivalent than that of sole crop.

Tomar *et al.* (1997) studied in a field trial on loam soil in winter seasons where wheat was grown alone or intercropped with *Lens culinaris* and *Cicer arietinum* in 2:2 row ratios. Seed yields of all crops were decreased by intercropping. Total plant N content was highest when *L. culinar* is grown alone. Increasing N fertilizer rate (0 - 90 kg N ha^{-1}) increased wheat grain yield but did not generally affect legume seed yields.

Verma and Mallick (1997) carried out a field trial in winter seasons with wheat and lentils grown alone or intercropped in a 4 : 2 row ratio. The wheat in pure stand was given 80 kg N + 16 kg P + 16 kg K ha^{-1}, while sole lentil received 20 kg N + 16 kg P ha^{-1}. Intercrops were given 8 different combinations of fertilizers. Wheat grain yield was 3.29 t ha^{-1} in pure stand and 2.73 - 3.12 t ha^{-1} when intercropped. Lentil seed yield was 1.53 t ha^{-1} in pure stand and 0.22 - 0.41 t ha^{-1} when intercropped. The highest wheat-equivalent yield and net returns were obtained when wheat was intercropped with lentils fertilized with 80 kg N + 16 kg P + 16 kg K ha^{-1}.

Singh *et al.* (1996) conducted an experiment where wheat and gram were grown in pure stands or in 1:1, 1: 2, 2:1 or 2:2 row ratios and given 0, 25, 50 or 75 kg N ha^{-1}. Yields of both crops were highest in pure stands. Wheat equivalent yield was highest when wheat was grown alone and in the 2:1 wheat: gram intercrop. Land equivalent ratios were always more than one in most intercropping treatments.

Hosamani *et al.* (1995) published the results of a field experiment with wheat which was intercropped with *Cicer arietinum* (chickpea), safflower or *Brassica juncea* in wheat: oilseeds row ratios of 3:1, 4:2 or 5:1. Mean wheat grain yields at the 3 row rations were 1.78, 1.50 and 1.91 t ha^{-1}, respectively. Wheat/safflower intercrop gave the highest wheat equivalent yield (3.07 t) and the highest net returns.

Haymes *et al.* (1994) compared wheat yield under sole cropping which was not severely depressed by intercropping with bean. It was found that wheat yield was significantly higher in alternate and within row spacing than in block spacing. Wheat yields increased with increasing density, and were decreased by increasing bean density. Weed biomass was significantly lower in all intercrop patters compared with sole cropping. In the block spacing the highest LER was obtained with wheat at 100% of the recommended sowing rate.

Varshney (1994) conducted an experiment during rabi season. Chickpeas and wheat were grown as sole crop or intercrop. Both crops only received the recommended NP fertilizer rate. Result showed that the sole wheat gave the highest chickpea equivalent yield. Application of the recommended fertilizer rate to wheat gave higher yields than application to both the crops.

Ali (1993) conducted a field experiment to determine the optimum fertilizer rate and row ratio of wheat and chickpeas in the late-sown under irrigated condition. Of the 3 populations tested (2:2, 2:1 and 3:1 row rations of wheat: chickpeas). the 2:2 row ratios allowed more light interception and transmission to the lower canopy and gave significantly higher yield (4.16 t ha^{-1} wheat equivalent) and land equivalent ratio (LER) than the other treatments.

Ardesana *et al.* (1993) stated that in recent years, many scientists are engaged to improve intercropping system for long time to achieve higher yield benefit. Among different cropping systems, intercropping system was found to be a better practice for increased growth, yield and development. In Bangladesh, pulse crops are generally grown without fertilizer or manure. However, it was found that the yield of pulse could be increased substantially by using fertilizers. Pulses, although fix nitrogen from atmosphere, it was also evident that nitrogen application became helpful to increase the yield, although there were controversies regarding the nitrogen. The pattern of N-fixation or utilization of other plant nutrients may have extra significance while practicing intercropping.

Atar *et al.* (1992) conducted a field experiment at New Delhi with wheat base intercropping system. It was observed that intercropping system ensured highest water use efficiency.

Dahatonde (1992) conducted a field experiment during the winter season; wheat was intercropped with French bean. Row ratios were 6:3 or 4:2 and the crops were given recommended fertilizers (100 kg N + 50 kg P + 50 kg ha^{-1} for wheat and 90 kg N + 50 kg P ha^{-1} for French bean). French bean grown alone produced the highest equivalent yield of 4.01 t ha^{-1} and the highest net returns. The best intercropping treatment producing a wheat equivalent yield of 3.60 t ha^{-1} was with 4:2 wheat/French bean intercrop.

Goldmon (1992) studied winter wheat relay cropped with soyabean. Results showed that sole wheat yielded slightly more than intercropped wheat. The land equivalent ratio was 1.18 with the wheat component comprising over 80% of the total. Among the intercropped treatments, soyabean grown in narrow row spacing and those with an indeterminate growth habit had better light interception.

Pandey *et al.* (1992) tested increasing N and P application rates (up to 40 kg ha^{-1} of each) and found that yields of wheat and *Cicer arietinum* grown as either intercrop or mixed crop were increased.

Hiremath *et al.* (1990) carried out a field trial in the rabi season on black clay soils. Wheat and soyabean were grown alone or intercropped in 12 different row ratios ranging from 1:1 to 4:3. The highest land equivalent ratio (1.33) was obtained from intercropping wheat and soyabean in a 1:2 row ratio, and the highest gross returns from a 3:1 row ratio.

Bautista (1988) observed that legumes grown as companion crops were found to be beneficial for the principal crop through nitrogen fixation. Moreover, legumes may help in the utilization of moisture from deeper soil layers. In intercropping of maize with cowpeas in both dry and rainy season cowpea gave the best result with respect to soil improvement and weed control. The author also reported that inclusion of legumes in the intercropping system was likely to be beneficial as they could fix atmospheric nitrogen into the soil and help in the utilization of soil moisture from deeper soil layers.

Mondal *et al.* (1986) reported that wheat chickpea was found to be most efficient with 1 irrigation in respect of land equivalent ratio, relative co-efficient, monetary advantage, relative net return and area time-equivalent ratio.

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

Gupta and Sharma (1984) reported that sorghum in paired rows of 30 + 60 cm did not reduce yield when compared to that from uniform rows of 45 cm and in addition a yield of 2.11 t ha^{-1} was obtained from pigeonpea resulting in an increase in LER by 1.26.

Hashem (1983) experimented to determine the profitability of intercropping systems; agronomically feasible technology may not always be accepted if it is economically viable. It is claimed that in almost all cases intercropping gave more monetary return than the sole crops.

Khan (1983) reported that the ratio of seed rate of crops in mixed or intercropping has got direct effect on the production and yield. Fertilizer application in the practice of mixed or intercropping is another important factor that affects the yield and production of the crops. The seed rate ratio or plant population is an important consideration in mixed intercropping practices. The best combination of seedling ratio for wheat and chickpea was found to be 50:100.

Islam *et al.* (1982) estimated that 80 per cent N fertilizer may be saved in a maize + blackgram intercropping. He found highest LER values (1.55) when maize was intercropped with black gram at 44,444 maize plants ha^{-1} and 1, 11, 111 black gram plants ha^{-1} with 20 kg N ha^{-1} instead of 120 kg N ha^{-1}. Miah (1982) obtained similar results where wheat and gram combination at 50:100 or 50:50 seed rate ratios gave more than 50% increased production over monoculture.

Bhuiyan (1981) investigated mixed cropping of gram with wheat under different proportion of normal seed rates. The highest LER of 1.47 was obtained at 100:75 seed rate ratio.

Rahman and Shamsuddin (1981) reported yield reduction of component crops in intercrop using 10, 20, 30 and 50 percent of wheat seed rate in wheat-lentil intercropping. They found that excluding 10% wheat seed rate, all reduced lentil yield significantly.

Singh (1981) reported that the intercropping of wheat with chickpea, lentil or lathyrus under adequate moisture conditions did not give higher total grain and dry matter production but was more profitable. Total monetary return was higher than sole crop and LER was greater than monocrop.

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

IRRI (1973) expressed that intercropping makes better use of sunlight, land and water. It may have some beneficial effects on pest and disease problems. In almost all the cases, it gave higher increased total production; monetary returns and greater resource use and increase the land productivity by almost 60 percent.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted to find out the effect of intercropping chickpea with sunflower under different row and spacing arrangements during the period from November 2008 to March 2009. A brief description of the experimental site, soil, climate, experimental design, treatments, cultural operations, data collection and analysis of different parameters for both sunflower and chickpea under the following headings:

3.1 Location

The experiment was carried out in rabi season at the experimental field of Agronomy Department Sher-e-Bangla Agricultural University, Dhaka-1207. The experimental field was located at $90^{0}22'$ E longitude and $23^{0}41'$ N latitude at an altitude of 8.6 meters above the sea level. The experimental site was located under the agro-ecological region of "Madhupur Tract" (AEZ No. 28).

3.2 Soil

The farm (experimental field) belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The physical and chemical properties of the soil are presented in Appendix I.

3.3 Climate

The experimental area is under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the rabi season (October-March). The weather data regarding temperature, rainfall, relative humidity and sunshine hour were collected from the weather station, Agargaon during the study period at the experimental site which is presented in Appendix II.

3.4 Crop/planting material

3.4.1 Description of sunflower cultivars

Seeds of sunflower variety DS-1 (Kironi) were used as a test crop for the study and it was collected from Bangladesh Agricultural Research Institute, Gazipur. It is an annual, erect, broadleaf plant with a strong taproot which prolific lateral spread of surface roots. Stems are usually round early in the season, angular and woody later in the season, and normally unbranched. Sunflower leaves are phototropic and will follow the sun's rays with a lag of 120 behind the sun's azimuth. This property has been shown to increase light interception and possibly photosynthesis. The variety made up of 1,000 to 2,000 individual flowers joined at a common receptacle. In temperate regions, sunflower requires approximately 11 days from planting to emergence, 33 days from emergence to head visible, 27 days from head visible to first anther, 8 days from first to last anther, and 30 days from last anther to maturity. This variety was developed from the reserved germplasm through selection process and released in the year 1982 (BARI, 2006) for cultivation at the rabi season.

3.4.2 Description of chickpea

Seeds of Chickpea variety BARI Chola-5 were used as a test crop for the study and the seeds of this variety were collected from Bangladesh Agricultural Research Institute, Gazipur. This variety was developed by BARI and exposed for cultivation in the year of 1996 (BARI, 2006) through the selection process among the different germplasms that generally has been cultivated in different area of Bangladesh. It is a spreading type plant and can also be easily grown in minimum or shading light.

3.5 Experimental treatments

Row and spacing arrangements of Sunflower : Chickpea are presented below

$T_1 = 1:1$

$T_2 = 1:2_{20}$

$T_3 = 1_{P70}:2_{20}$

$T_4 = 1_{P70}:2_{30}$

$T_5 = 1_{P70}:2_{40}$

$T_6 = 1_{P70}:3_{20}$

$T_7 = 1_{P100}:3_{20}$

$T_8 = 1_{P100}:3_{30}$

$T_9 = 1_{P100}:4_{20}$

T_{10} = Sole sunflower (50 cm × 25 cm)

T_{11} = Sole chickpea (40 cm × 10 cm)

3.6 Details of the treatments

T_1 (1:1) = In 1:1 row arrangement, sunflower was sown maintaining row to row distance of 50 cm and the chickpea row was sown in the middle of two adjacent sunflower rows.

T_2 ($1:2_{20}$) = In $1:2_{20}$ row arrangement, sunflower was sown maintaining row to row distance of 50 cm and two rows of chickpea were sown in between two adjacent sunflower rows maintaining row to row distance of 20 cm.

T_3 ($1_{P70}:2_{20}$) = In $1_{P70}:2_{20}$ row arrangement, sunflower was sown in paired rows (30 cm apart) and two rows of chickpea were sown within the middle space of 70 cm between paired sunflower rows maintaining chickpea row to row distance of 20 cm.

T_4 ($1_{P70}:2_{30}$) = In $1_{P70}:2_{30}$ row arrangement, sunflower was sown in paired rows (30 cm apart) and two rows of chickpea were sown at the middle space of 70 cm between paired sunflower rows maintaining chickpea row to row distance of 30 cm.

T_5 (1_{P70}:2_{40}) = In 1_{P70}:2_{40} row arrangement, sunflower was sown in paired rows (30 cm apart) and two rows of chickpea were sown at the middle space of 70 cm between paired sunflower rows maintaining chickpea row to row distance of 40 cm.

T_6 (1_{P70}:3_{20}) = In 1_{P70}:3_{20} row arrangement, sunflower was sown in paired rows (30 cm apart) and three rows of chickpea were sown at the middle space of 70 cm between paired sunflower rows maintaining chickpea row to row distance of 20 cm.

T_7 (1_{P100}:3_{20}) = In 1_{P100}:3_{20} row arrangement, sunflower was sown in paired rows (30 cm apart) and three rows of chickpea were rows at the middle space of 100 cm between paired sunflower rows maintaining chickpea rows to rows distance of 20 cm.

T_8 (1_{P100}:3_{30}) = In 1_{P100}:3_{30} row arrangement, sunflower was sown in paired rows (30 cm apart) and three rows of chickpea were sown at the middle space of 100 cm between paired sunflower rows maintaining chickpea row to row distance of 30 cm.

T_9 (1_{P100}:4_{20}) = In 1_{P100}:4_{20} row arrangement, sunflower was sown in paired rows (30 cm apart) and four rows of chickpea were sown at the middle space of 100 cm between paired sunflower rows maintaining chickpea row to row distance of 20 cm.

T_{10} [Sole sunflower (50 cm × 25 cm)] = Sole sunflower was sown using row to row distance of 50 cm and plant to plant distance of 25 cm.

T_{11} [Sole chickpea (40 cm × 10 cm)] = Sole chickpea was sown using row to row distance of 40 cm and plant to plant distance 10 cm.

3.7 Number of rows, number of plants row^{-1}, plants plot^{-1} and plants m^{-2} in different treatments

Treatment	Crop	Number of rows plot^{-1} (6 m^{-2})	Number of plants row^{-1}	Number of plants plot^{-1} (6 m^{-2})	Number of plants m^{-2}
T_1	Sunflower	6	8	48	8
	Chickpea	6	40	240	40
T_2	Sunflower	6	8	48	8
	Chickpea	12	40	480	80
T_3	Sunflower	6	8	48	8
	Chickpea	5	40	200	33
T_4	Sunflower	6	8	48	8
	Chickpea	5	40	200	33
T_5	Sunflower	6	8	48	8
	Chickpea	5	40	200	33
T_6	Sunflower	6	8	48	8
	Chickpea	8	40	320	53
T_7	Sunflower	6	8	48	6
	Chickpea	6	40	240	40
T_8	Sunflower	6	8	48	8
	Chickpea	6	40	240	40
T_9	Sunflower	6	8	48	8
	Chickpea	8	40	320	53
T_{10}	Sunflower	54	8	432	72
T_{11}	Chickpea	312	40	12,480	2080

3.8 Layout of the experiment

The experiment was laid out in Randomized Complete Block Design (BCBD) with three replications. The experimental unit was divided into three blocks each of which representing a replication. Each block was divided into 11 plots in which 11 treatments were applied at random. So, the total number of unit plots in the entire experimental plot was 3 × 11 = 33. Size of each unit plot was 3.0 m × 2.0 m = 6.0 m^2. The distance maintained between two plots was 0.5 m and between blocks it was 1 m.

3.9 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from a 0 - 15 cm soil depth. The samples were collected by means of an auger from different location covering the whole experimental plot and the collected soil was mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the sample was air-dried and sieved through a 10 mm sieve and stored in a clean plastic container for physical and chemical analysis.

3.10 Details of the field operations

The particular of the cultural operations carried out during the experimentation are presented below:

3.10.1 Land preparation

The experimental field was first opened on November 5, 2008 with the help of a power tiller and prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering to have a desirable fine tilth. The visible larger clods were hammered to break into small pieces. All kinds of weeds and residues of previous crop were removed from the field. Individual plots were cleaned and finally leveled with the help of wooden plank.

3.10.2 Fertilizer application

The experimental field was fertilized with N, P_2O_5, KCl, $CaSO_42H_2O$, $ZnSO_4H_2O$ at the rate of 200, 200, 150, 170 and 10 kg ha^{-1} respectively. The whole amount of P_2O_5, KCl, $CaSO_42H_2O$, $ZnSO_4H_2O$ and one third of N were mixed with soil at the time of final land preparation. The remaining urea was applied in two installments after 30 and 50 DAS as top dressing. Fertilizer dose of sunflower was followed in sole sunflower and all the intercropped plots, whereas in sole chickpea plots, that of chickpea was followed.

3.10.3 Collection and sowing of seeds

The seeds of sunflowers were sown on November 15, 2008. Furrows were made with hand rakes for sowing. Seeds were sown continuously in line. The line to line distance was maintained as per treatment. After sowing seeds were covered with soil and slightly pressed by hand.

The chickpea seeds were sown when the land was at field capacity condition at the same days on November 15, 2008. Seeds were sown continuous with maintaining line to line distance as per treatment. After sowing, seeds were covered with soil and slightly pressed by hand.

3.10.4 Irrigation

The experimental plot was irrigated two times. The first irrigation was done at flowering stage and second was applied at grain filling stage of chickpea. Proper drainage system was maintained to remove the excess amount of water from the plot.

3.10.5 Pest management

In the whole period of experimentation, no infestation of diseases and pest were found. Special attention were undertaken to protect the crop from the attack of parrots, pigeons and other birds.

3.10.6 Harvesting and sampling

The crop chickpea was harvested at maturity on March 11, 2009 and the sunflower was harvested at March 24, 2009. Samples were collected from different places of each plot leaving undisturbed middle 4 rows in the centre. The selected sample plants were then tagged and carefully carried to the Agronomy field laboratory in order to collect data. The crop bundles were sun dried on the threshing floor. The seeds of sunflower and chickpea were separated by beating with the wooden stick and dried for constant moisture and the weight were recorded and converted into t ha^{-1} basis.

3.11 Recording of data

The following data were recorded during the study period:

3.11.1 Data of soil moisture and light intensity of the field

1. Soil moisture
2. Light intensity

3.11.2 Data of sunflower

1. Plant height
2. Leaf area at 80 DAS (cm^2)
3. Head diameter (cm)
4. Number of filled grains $plant^{-1}$
5. Number of unfilled grains $plant^{-1}$
6. Total number of grains $plant^{-1}$
7. Dry matter content of leaf
8. Dry matter content of stem
9. Total dry matter content of plant
10. Weight of 1000 seeds
11. Seed yield $hectare^{-1}$
12. Relative yield

3.11.3 Data of chickpea

1. Plant height
2. Number of branches $plant^{-1}$
3. Dry matter content of leaf
4. Dry matter content of stem
5. Total dry matter content of plant

6. Weight of 1000 seeds
7. Seed yield hectare^{-1}
8. Relative yield

3.11.4 Data of land equivalent ratio, equivalent yield and N, P, K

1. Land equivalent ratio
2. Equivalent yield
3. Combined yield of sunflower and chickpea
4. Economic analysis
5. NPK concentration on soil after crop harvest

3.11.1 Data of soil moisture and light intensity of the field

3.11.1.1 Soil moisture

The fresh weight of soil was recorded from each unit plot. The weight of the soil was recorded immediately after harvest. After recording the fresh weight of the soil it was dried well in sun. The sun-dried soils were then dried in an oven at 65^{0}C for 72 hours, until constant weight was achieved. It was recorded at 20, 40, 60 and 80 DAS. The recorded weight, after oven drying, was the dry weight of soil. Soil moisture was calculated following the formula on dry weight basis -

$$\text{Soil moisture (\%)} = \frac{\text{Initial weight} - \text{Oven dry weight}}{\text{Oven dry weight}} \times 100$$

3.11.1.2 Light intensity

Light intensity was measured at 60 DAS when both sunflower and chickpea reached at full vegetative stage. It was measured using Lutron Luxmeter Model Lx-101 and expressed in Lux. Light intensity was measured for sunflower at the top most position of foliage and for chickpea it was measured at upper, middle and base of the foliage.

3.11.2 Data of sunflower

3.11.2.1 Plant height of sunflower

The height of sunflower was recorded in centimeter (cm) at 20, 40, 60 and 80 days after sowing (DAS) and at harvest. To measure plant height ten plants were randomly selected from each plot and tagged. The height was measured from soil surface to tip of the plant and mean height was recorded.

3.11.2.2 Leaf area at 80 DAS (cm^2) of sunflower

The leaves of 10 randomly selected plants of each plot were measured by length and width at 80 days after sowing (DAS).

3.11.2.3 Head diameter (cm) of sunflower

Head diameter of sunflower was measured in centimeter by using a measuring scale. Measurement was taken from two opposite directions.

3.11.2.4 Number of filled grains $plant^{-1}$ of sunflower

The total number of filled grains $plant^{-1}$ was counted on the basis of eye observation. Data were recorded as the average of ten plants selected at random from the inner rows of each plot during the time of harvest.

3.11.2.5 Number of unfilled grains $plant^{-1}$ of sunflower

The total number of unfilled grains $plant^{-1}$ of sunflower was counted. Data were recorded as the average of ten plants selected at random from the inner rows of each plot during the time of harvest.

3.11.2.6 Total number of grains $plant^{-1}$ of sunflower

The total number of grains $plant^{-1}$ of sunflower was counted. Data were recorded as the average of ten plants selected at random from the inner rows of each plot during the time of harvest.

3.11.2.7 Dry matter content of leaf of sunflower

After harvesting 100 g of leaf sample previously sliced into very thin pieces were put into envelop and placed in oven and dried at 70^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight of the sample was taken. The dry matter contents of leaves were expressed in gram.

3.11.2.8 Dry matter content of stem of sunflower

After harvesting 100 g of stem sample previously sliced into very thin pieces were put into envelop and placed in oven and dried at 70^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight stem of the sample was taken. The dry matter contents of stem were expressed in gram.

3.11.2.9 Total dry matter content of plant of sunflower

Total dry matter content of sunflower plant was measured by adding dry matter content of leaf and stem.

3.11.2.10 Weight of 1000 seeds of sunflower

Thousand seeds of sunflower were taken from the seed sample and weighed at about 12% moisture level using an electric balance and recorded as per.

3.11.2.11 Seed yield hectare^{-1} of sunflower

After threshing, proper drying (12% moisture level) and cleaning of sunflower, yield of each sample plot was weighed and values were converted to t ha^{-1}.

3.11.2.12 Relative yield of sunflower

Relative yield was measured dividing intercropped yield of sunflower by the sole crop yield of sunflower. Relative yield was calculated by using the following formula-

$$\text{Relative yield of sunflower} = \frac{\text{Yield of the intercropped sunflower}}{\text{Yield of the sole sunflower}}$$

3.11.3 Data of chickpea

3.11.3.1 Plant height of chickpea

The height of chickpea was recorded in centimeter (cm) at 20, 40, 60 and 80 days after sowing (DAS) and at harvest. To measure plant height ten plants were randomly selected from each plot and tagged. The height was measured from soil surface to tip of the plant and mean height was recorded.

3.11.3.2 Number of branches plant^{-1} of chickpea

The total number of branches per plant of chickpea was counted. Data were recorded as the average of ten plants selected at random from the inner rows of each plot starting from 20 to 80 DAS at 20 days interval and at harvest.

3.11.3.3 Dry matter content of leaf of chickpea

After harvesting 100 g of leaf sample previously sliced into very thin pieces were put into envelop and placed in oven and dried at 70^{0}C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight of the sample was taken. The dry matter contents of leaves were expressed in gram.

3.11.3.4 Dry matter content of stem of chickpea

After harvesting 100 g of stem sample previously sliced into very thin pieces were put into envelop and placed in oven and dried at 70^{0}C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final stem weight of the sample was taken. The dry matter contents of stem were expressed in gram.

3.11.2.5 Total dry matter content of plant of chickpea

Total dry matter content of chickpea plant was measured by adding dry matter content of leaf and stem.

3.11.3.6 Weight of 1000 seeds of chickpea

Thousand seeds of chickpea were taken from the seed sample and weighed at about 12% moisture level using an electric balance and weight was recorded.

3.11.3.7 Seed yield hectare^{-1} of chickpea

After threshing, proper drying (12% moisture level) and cleaning of chickpea, yield of each sample plot was weighed and values were converted to t ha^{-1}.

3.11.3.8 Relative yield of chickpea

Relative yield was measured dividing intercropped yield of chickpea by the sole crop yield of chickpea. Relative yield was calculated by using the following formula according to Willey (1979) -

$$\text{Relative yield of chickpea} = \frac{\text{Yield of the intercropped chickpea}}{\text{Yield of the sole chickpea}}$$

3.11.4 Data of land equivalent ratio, equivalent yield, economic analysis and N, P, K concentration

3.11.4.1 Land equivalent ratio

In order to compare the difference among the treatments, land equivalent ratio (LER) was calculated. LER value was computed from the grain yield according to the following formula according to Willey (1979) –

$$\text{LER} = \frac{\text{Yield of the intercropped sunflower}}{\text{Yield of the sole sunflower}} + \frac{\text{Intercrop yield of chickpea}}{\text{Yield of sole chickpea}}$$

LER in its simplest form has been defined as the relative area of the sole crop that would be required to produce the yield achieved by intercropping.

3.11.4.2 Equivalent yield (t ha^{-1})

In the intercropping system, equivalent yields were used as criteria for evaluating the productivity. Sunflower equivalent was calculated and it was computed by converting the yield of chickpea in to the yield of main crop sunflower on the basis of market prices using the following formula according to Willey (1979) -

$$\text{Sunflower equivalent yield} = \text{Ys} + \frac{\text{Yc} \times \text{Pc}}{\text{Ps}}$$

Where,

Ys = Seed yield of sunflower (t ha^{-1})

Yc = Seed yield of chickpea (t ha^{-1})

Ps = Market price of sunflower seed (Tk. 60 kg^{-1})

Pc = Market price of chickpea seed (Tk. 52 kg^{-1})

Similarly,

$$\text{Chickpea equivalent yield} = Yc + \frac{Ys \times Ps}{Pc}$$

Where,

Ys = Seed yield of sunflower (t ha^{-1})

Yc = Seed yield of chickpea (t ha^{-1})

Ps = Market price of sunflower seed (Tk. 60 kg^{-1})

Pc = Market price of chickpea seed (Tk. 52 kg^{-1})

3.11.4.3 Combined yield of sunflower and chickpea

Combined yield of sunflower and chickpea was measured by adding sunflower and chickpea yield in every plot and converted into hectare yield.

3.11.4.4 Economic analysis

The cost of production was analyzed in order to find out the most economic combination of sunflower and chickpea intercropping under different row and spacing arrangements. All input cost include the cost for lease of land and miscellaneous were considered in computing the cost of production. The market price of sunflower and chickpea was considered for estimating the cost and return. The benefit cost ratio (BCR) was calculated as follows:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return per hectare (Tk.)}}{\text{Total cost of production per hectare (Tk.)}}$$

3.11.4.5 NPK concentration on soil after crop harvest

Total nitrogen

Total N content of soil were determined following the Micro Kjeldahl method. The analysis was made by SRDI. One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 6 ml H_2SO_4 were added. The flasks were swirled and heated at 200^0C and added with it 3 ml of H_2O_2 and then heating at 360^0C. It was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al.*, 1982).

Then 20 ml digest solution was transferred into the distillation flask, then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which was marked to indicate a volume of 50 ml and the flask was placed under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Sufficient amount of 10N-NaOH solutions was added in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink. The amount of N was calculated using the following formula:

$$\% N = (T\text{-}B) \times N \times 0.014 \times 100/S$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated the standard P curve (Page *et al.*, 1982).

Exchangeable potassium

Exchangeable K was determined by 1N NH_4OAc (pH 7) extraction methods by using flame photometer calibrated with a standard curve (Page *et al.*, 1982).

3.12 Statistical analysis

The collected data were complied and analyzed to find out the statistical significance among the level of factors. The collected data were analyzed by MSTAT–C software. The means for all recorded data were calculated and the analyses of variance of all characters were performed. The mean differences were evaluated by Duncan's Multiple Range Test (DMRT) at 0.05 level of probability (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

The experiment was conducted to find out the intercropping effect of chickpea with sunflower under different row and spacing arrangements. Data on soil moisture, light intensity, growth parameter, yield attributes and yield were recorded for sunflower and chickpea. Land equivalent ratio, equivalent yield, total N, P, K were also estimated in post harvest soil. The analyses of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendix III-XI. The results have been presented and possible interpretations are given under the following headings:

4.1 Soil moisture and light intensity

4.1.1 Soil moisture

Soil moisture of the sunflower and chickpea intercropped field showed significant variation at 20, 40, 60 and 80 DAS due to different treatments (Table 1). At 20, 40, 60 and 80 DAS the maximum soil moisture (32.62%, 31.10%, 34.18% and 35.20%) was recorded from T_5 (1_{p70}:2_{40}) which was however, statistically identical with other treatment except T_{10} [sole sunflower (50 cm × 25 cm)] which was followed by T_{11} (sole chickpea). On the other hand, at the same DAS the minimum soil moisture (26.25%, 25.10%, 27.00% and 27.60%), respectively was recorded from T_{10}. Data revealed that intercropped plot preserved maximum soil moisture than the sole cropped plot under the present trial. Probably, in the intercropped plot more soil moisture was preserved by preventing direct falling of sunlight on the soil. On the other hand, it also prevented evaporation of soil moisture from the field by covering the surface of the soil. Moreover, legumes might have helped in the utilization of moisture from deeper soil layers (Bautista, 1988). Similar results were also reported by Singh (1981), Govind and Ravi (2007), Manisha *et al.* (2007), Dutta and Bandyopadhyay (2007) and Ahlawat *et al.* (2005) from their earlier experiments in intercropped field.

Table 1. Effect of sunflower-chickpea intercropping under different row and spacing arrangements on soil moisture content in the field

Treatment	Soil moisture (%)			
	20 DAS	40 DAS	60 DAS	80 DAS
T_1	31.10 ab	29.75 a	32.45 ab	34.03 a
T_2	30.38 abc	29.95 a	31.90 ab	32.91 ab
T_3	32.05 a	30.62 a	33.05 ab	34.45 a
T_4	32.23 a	30.08 a	33.28 ab	34.20 a
T_5	32.62 a	31.10 a	34.18 a	35.20 a
T_6	32.00 a	31.03 a	33.80 ab	34.74 a
T_7	29.90 abc	28.53 ab	30.05 bcd	31.90 ab
T_8	29.75 abc	28.90 a	31.18 abc	32.50 ab
T_9	29.60 abc	28.30 ab	29.95 bcd	31.35 abc
T_{10}	26.25 c	25.10 c	27.00 d	27.60 c
T_{11}	27.73 bc	25.75 bc	27.80 cd	29.10 bc
SE	1.276	0.967	1.222	1.322
Significance level	0.05	0.01	0.01	0.01
CV(%)	7.29	5.77	6.75	7.04

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

Row and spacing arrangements of sunflower: Chickpea:

$T_1 = 1:1$ $T_2 = 1:2_{20}$
$T_3 = 1_{P70}:2_{20}$ $T_4 = 1_{P70}:2_{30}$
$T_5 = 1_{P70}:2_{40}$ $T_6 = 1_{P70}:3_{20}$
$T_7 = 1_{P100}:3_{20}$ $T_8 = 1_{P100}:3_{30}$
$T_9 = 1_{P100}:4_{20}$ T_{10} = Sole sunflower (50 cm × 25 cm)
T_{11} = Sole chickpea (40 cm × 10 cm)

1p = one paired rows of maize followed by 70 or 100 cm gap

1:1 = One row of sunflower followed by one row of chickpea

2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings

4.1.2 Light intensity

Statistically significant variation was recorded for light intensity of the sunflower and chickpea intercropped field in the context of chickpea plant but regarding sunflower plot it was statistically non-significant due to different treatments (Table 2). In case of sunflower, light intensity varied from 281.00 to 287.00 Lux. The maximum light intensity (287.00 Lx) was observed from T_2 ($1:2_{20}$) and the minimum light intensity (281.00 Lx) was recorded from T_9 ($1_{p100}:4_{20}$). In case of chickpea, the maximum light intensity (287.33 Lx, 285.00 Lx and 284.33 Lx) was recorded from T_{11} (sole chickpea) at the point of upper, middle and basement of the plant, respectively, while the minimum light intensity (167.00 Lx, 147.00 Lx and 125 Lx) was found from T_9 ($1_{p100}:4_{20}$) at the same position. Data revealed that sole crop received maximum light than the other crops but in case of different combination of row and spacing it varied within a significant range under the present trial. Xiao *et al.* (2008) reported that intercropping patterns must have harmoniously reasonable population structure, good ventilation and light transmission.

4.2 Yield contributing characters and yield of sunflower

4.2.1 Plant height

Significant difference was recorded for plant height of sunflower at 20, 40, 60, 80 DAS and at harvest due to different treatments (Table 3). At 20, 40, 60, 80 DAS and at harvest the longest plant (21.70, 55.00, 77.83, 98.20 and 112.67 cm) was obtained from T_{10} [sole sunflower (50 cm × 25 cm)] which was however, statistically identical to T_5 ($1_{p70}:2_{40}$) and T_6 ($1_{p70}:3_{20}$) and the shortest plant (16.50, 46.13, 62.60, 84.00 and 100.33 cm), respectively for same days was recorded from T_9 ($1_{p100}:4_{20}$). Intercropped probably creates a competition between the plant species regarding light receiving and nutrient absorption that leads to the vegetative growth and the ultimate results is the longest plant. Nargis *et al.* (2004) observed the highest plant height with intercropping condition.

Table 2. Effect of sunflower-chickpea intercropping under different row and spacing arrangements on light intensity in the field

Treatment	Light intensity (lux)			
	Sunflower	Chickpea		
		Upper	Middle	Base
T_1	281.00	168.33 c	154.00 cde	131.00 c
T_2	287.00	169.00 c	151.33 de	129.00 c
T_3	282.00	177.00 bc	161.00 cd	135.00 c
T_4	283.00	175.33 bc	158.67 cde	132.00 c
T_5	285.00	186.33 b	163.00 c	138.33 c
T_6	285.00	178.33 bc	159.00 cde	136.00 c
T_7	283.00	16 7.00 c	149.67 cde	126.00 c
T_8	286.00	165. 67 c	148.00 de	129.00 c
T_9	281.00	167.0 0 c	147.00 e	125.00 c
T_{10}	285.00	285.00 a	178.00 b	153.00 b
T_{11}	284.00	287.33 a	285.00 a	284.33 a
SE	4.407	4.592	4.073	4.295
Significance level	NS	0.01	0.01	0.01
CV(%)	6.69	9.11	8.18	5.05

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

Row and spacing arrangements of sunflower: Chickpea:

$T_1 = 1:1$ — $T_2 = 1:2_{20}$

$T_3 = 1_{P70}:2_{20}$ — $T_4 = 1_{P70}:2_{30}$

$T_5 = 1_{P70}:2_{40}$ — $T_6 = 1_{P70}:3_{20}$

$T_7 = 1_{P100}:3_{20}$ — $T_8 = 1_{P100}:3_{30}$

$T_9 = 1_{P100}:4_{20}$ — T_{10} = Sole sunflower (50 cm × 25 cm)

T_{11} = Sole chickpea (40 cm × 10 cm)

1p = one paired rows of maize followed by 70 or 100 cm gap

1:1 = One row of sunflower followed by one row of chickpea

2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings

Table 3. Effect of sunflower-chickpea intercropping under different row and spacing arrangements on plant height of sunflower

Treatment	Plant height of sunflower at				
	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T_1	18.30 bc	47.30 b	66.20 b	88.50 bcd	104.00 bc
T_2	18.60 bc	47.40 b	66.60 b	89.20 bcd	104.00 bc
T_3	19.50 abc	48.20 b	68.30 b	92.00 abc	108.00 abc
T_4	19.10 abc	48.00 b	68.00 b	90.50 bcd	105.00 bc
T_5	20.10 ab	51.30 ab	71.20 ab	94.00 ab	109.00 ab
T_6	19.40 abc	50.60 ab	70.00 ab	92.10 abc	108.00 abc
T_7	17.10 bc	46.30 b	64.40 b	85.10 cd	102.00 bc
T_8	17.20 bc	46.60 b	65.10 b	86.30 bcd	103.00 bc
T_9	16.50 c	46.13 b	62.60 b	84.00 d	100.33 c
T_{10}	21.70 a	55.00 a	77.83 a	98.20 a	112.67 a
SE	0.891	1.522	2.685	2.336	2.275
Significance level	0.05	0.01	0.05	0.01	0.05
CV(%)	8.23	5.41	6.84	7.50	8.73

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

Row and spacing arrangements of sunflower: Chickpea:

$T_1 = 1:1$

$T_2 = 1:2_{20}$

$T_3 = 1_{P70}:2_{20}$

$T_4 = 1_{P70}:2_{30}$

$T_5 = 1_{P70}:2_{40}$

$T_6 = 1_{P70}:3_{20}$

$T_7 = 1_{P100}:3_{20}$

$T_8 = 1_{P100}:3_{30}$

$T_9 = 1_{P100}:4_{20}$

T_{10} = Sole sunflower (50 cm × 25 cm)

1p = one paired rows of maize followed by 70 or 100 cm gap

1:1 = One row of sunflower followed by one row of chickpea

2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings

4.2.2 Leaf area at 80 DAS (cm^2)

Leaf area of sunflower at 80 DAS showed significant variations due to different treatments (Table 4). The highest leaf area (241.67 cm^2) was observed from T_{10} [sole sunflower (50 cm × 25 cm)] which was however, statistically similar to T_5 ($1_{p70}:2_{40}$) and T_6 ($1_{p70}:3_{20}$) and the lowest leaf area (214.00 cm^2) was found from T_9 ($1_{p100}:4_{20}$). Oleksy and Szmigiel (2001) reported that mixed or intercropping was advantageous for the farmers as it increased the total production through increasing leaf area.

4.2.3 Head diameter (cm)

Head diameter of sunflower showed significant differences due to different treatments under the trial (Figure 1). The highest head diameter of sunflower (12.42 cm) was found from T_{10} [sole sunflower (50 cm × 25 cm)] which was closely followed by the other treatments of the experiment. But the lowest head diameter of sunflower (10.05 cm) was recorded from T_9 ($1_{p100}:4_{20}$). Ahmad *et al.* (1998) reported similar findings.

4.2.4 Number of filled grains plant^{-1}

Number of filled grains plant^{-1} of sunflower varied significantly for different treatments (Table 4). The maximum filled grains per plant of sunflower (277.00) were recorded from T_{10} [sole sunflower (50 cm × 25 cm)] and the minimum number of filled grains per plant of sunflower (241.00) was obtained from T_9 ($1_{p100}:4_{20}$). On the other hand, other treatments of the experiment showed within the value with significant differences.

4.2.5 Number of unfilled grains plant^{-1}

Significant variation was recorded for number of unfilled grains plant^{-1} of sunflower due to different treatments (Table 4). The minimum unfilled grains of sunflower (55.10) were recorded from T_{10} [sole sunflower (50 cm × 25 cm)] and the maximum number of unfilled grains of sunflower (69.50) was found from T_9 ($1_{p100}:4_{20}$) which was statistically identical with T_8 and T_7 treatments.

Table 4. Effect of sunflower-chickpea intercropping under different row and spacing arrangements on leaf area at 90 DAS, number of filled, unfilled and total grains plant^{-1} of sunflower

Treatment	Leaf area at 90 DAS	Number of filled grains plant^{-1}	Number of unfilled grains plant^{-1}	Total number of grains plant^{-1}
T_1	221.00 bc	250.00 bc	66.10 ab	316.10
T_2	225.00 bc	261.00 abc	66.40 ab	327.40
T_3	229.00 abc	262.00 abc	63.00 ab	325.00
T_4	229.00 abc	262.00 abc	64.10 ab	326.10
T_5	233.00 ab	270.00 ab	61.40 b	331.40
T_6	231.00 ab	262.00 abc	63.20 ab	325.20
T_7	217.00 bc	246.00 c	68.20 a	314.20
T_8	221.00 bc	249.00 bc	68.00 a	317.00
T_9	214.00 c	241.00 c	69.50 a	310.50
T_{10}	241.67 a	277.00 a	55.10 c	332.10
SE	4.474	6.832	1.934	7.659
Significance level	0.05	0.05	0.01	NS
CV(%)	6.64	7.59	5.19	6.11

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

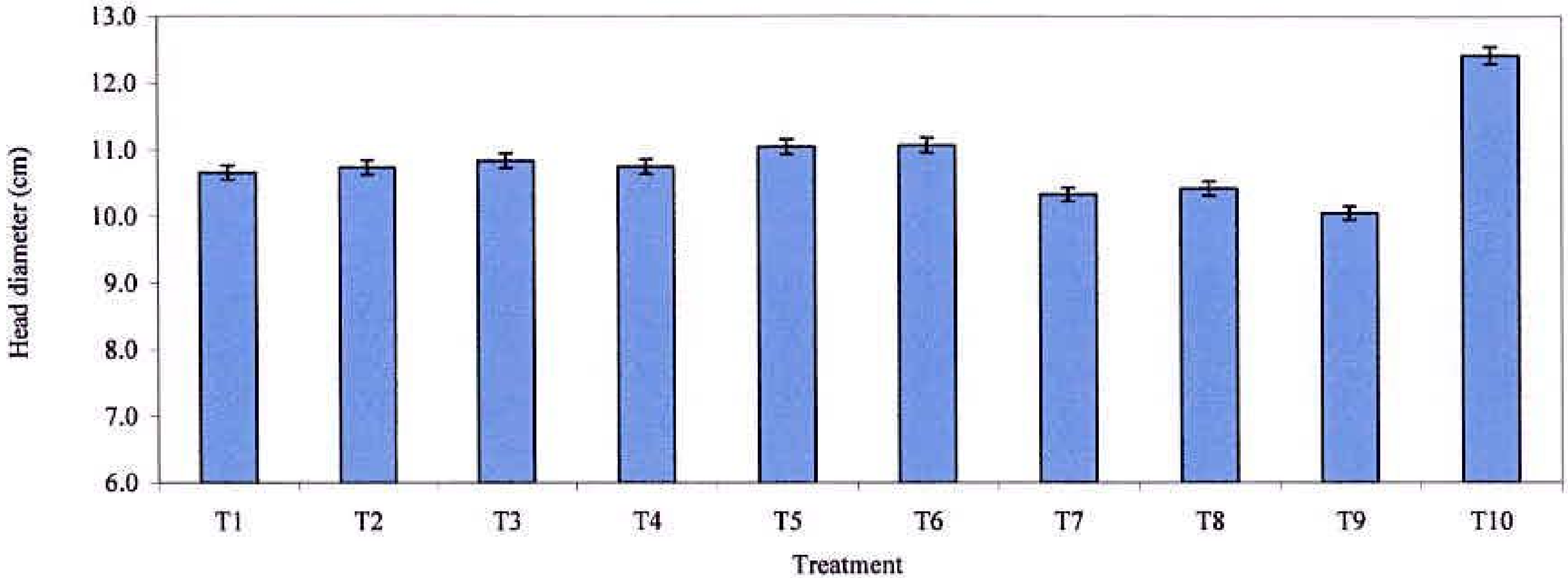
Row and spacing arrangements of sunflower: Chickpea:

$T_1 = 1{:}1$ | $T_2 = 1{:}2_{20}$
$T_3 = 1_{P70}{:}2_{20}$ | $T_4 = 1_{P70}{:}2_{30}$
$T_5 = 1_{P70}{:}2_{40}$ | $T_6 = 1_{P70}{:}3_{20}$
$T_7 = 1_{P100}{:}3_{20}$ | $T_8 = 1_{P100}{:}3_{30}$
$T_9 = 1_{P100}{:}4_{20}$ | T_{10} = Sole sunflower (50 cm × 25 cm)

1p = one paired rows of maize followed by 70 or 100 cm gap

1:1 = One row of sunflower followed by one row of chickpea

2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings



$T_1 = 1:1$ $T_2 = 1:2_{20}$ $T_3 = 1_{P70}:2_{20}$ $T_4 = 1_{P70}:2_{30}$

$T_5 = 1_{P70}:2_{40}$ $T_6 = 1_{P70}:3_{20}$ $T_7 = 1_{P100}:3_{20}$ $T_8 = 1_{P100}:3_{30}$

$T_9 = 1_{P100}:4_{20}$ T_{10} = Sole sunflower (50 cm × 25 cm)

1p = one paired rows of maize followed by 70 or 100 cm gap
1:1 = One row of sunflower followed by one row of chickpea
2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings

Figure 1. Effect of sunflower-chickpea intercropping under different row and spacing arrangements on head diameter of sunflower (Vertical bar represents SE values)

4.2.6 Total number of grains plant^{-1}

Number of total grains plant^{-1} of sunflower showed non-significant differences due to different treatments (Table 4). The maximum total grains of sunflower (332.10) were observed from T_{10} [sole sunflower (50 cm × 25 cm)] and the minimum (310.50) was recorded from T_9 (1_{p100}:4_{20}). Thakur *et al.* (2004) reported that the highest number of seeds per head (279) from sole cropping of sunflower.

4.2.7 Dry matter content of leaf

Due to the application of different treatments dry matter content of leaf of sunflower showed significant variation (Table 5). The maximum dry matter content of leaf (8.22 g) was found from T_{10} [sole sunflower (50 cm × 25 cm)] which was however, statistically identical (8.13 g and 8.05 g) to T_5 (1_{p70}:2_{40}) and T_6 (1_{p70}:3_{20}) and the minimum (7.54 g) was obtained from T_9 (1_{p100}:4_{20}).

4.2.8 Dry matter content of stem

Dry matter content of stem of sunflower varied significantly due to different treatments (Table 5). The maximum dry matter content of stem (9.64 g) was recorded from T_{10} [sole sunflower (50 cm × 25 cm)] which was however, statistically identical (9.36 g and 9.22 g) to T_5 (1_{p70}:2_{40}) and T_6 (1_{p70}:3_{20}) and the minimum dry matter content of stem (8.52 g) was found from T_9 (1_{p100}:4_{20}).

4.2.9 Total dry matter content of plant

Total dry matter content of plant of sunflower varied significantly due to different treatments (Table 5). The maximum total dry matter content of plant (17.86 g) was recorded from T_{10} [sole sunflower (50 cm × 25 cm)] which was however, statistically identical (17.49 g and 17.27 g) to T_5 (1_{p70}:2_{40}) and T_6 (1_{p70}:3_{20}) and the minimum (16.06 g) was found from T_9 (1_{p100}:4_{20}).

4.2.10 Weight of 1000 seeds

Statistically significant variation was observed for weight of 1000 seeds of sunflower due to different treatments (Figure 2). The highest weight of 1000 seeds of sunflower (65.20 g) was found from T_{10} [sole sunflower (50 cm × 25 cm)] and the lowest weight (60.80 g) was recorded from T_9 (1_{p100}:4_{20}).

Table 5. Effect of sunflower-chickpea intercropping under different row and spacing arrangements on yield contributing characters and yield of sunflower

Treatment	Dry matter content of leaf (g)	Dry matter content of stem (g)	Total dry matter content of plant (g)	Yield (t/ha)	Relative yield
T_1	7.89 abcd	8.82 bcde	16.71 bcd	1.86 b	0.84 b
T_2	8.00 abc	9.01 bcde	17.01 bc	1.84 b	0.83 b
T_3	8.05 abc	9.15 abcd	17.20 abc	1.99 b	0.89 b
T_4	8.02 abc	9.08 bcd	17.10 abc	1.91 b	0.86 b
T_5	8.13 ab	9.36 ab	17.49 ab	2.04 ab	0.92 ab
T_6	8.05 abc	9.22 abc	17.27 abc	2.02 ab	0.91 ab
T_7	7.61 cd	8.61 de	16.22 d	1.53 c	0.69 c
T_8	7.74 bcd	8.75 cde	16.49 cd	1.59 c	0.71 c
T_9	7.54 d	8.52 e	16.06 d	1.57 c	0.71 c
T_{10}	8.22 a	9.64 a	17.86 a	2.23 a	1.00 a
SE	0.134	0.166	0.141	0.073	0.033
Significance level	0.05	0.01	0.01	0.01	0.01
CV(%)	12.93	9.19	6.44	6.77	6.77

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

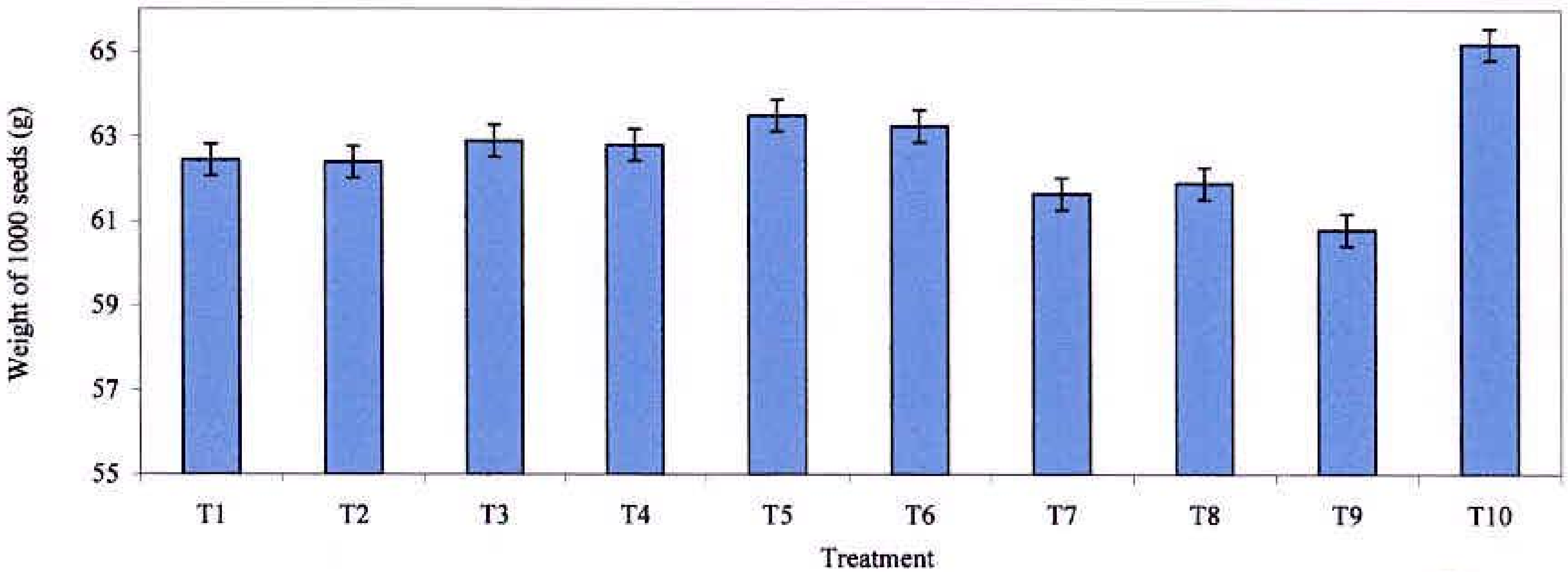
Row and spacing arrangements of sunflower: Chickpea:

$T_1 = 1:1$ $T_2 = 1:2_{20}$
$T_3 = 1_{P70}:2_{20}$ $T_4 = 1_{P70}:2_{30}$
$T_5 = 1_{P70}:2_{40}$ $T_6 = 1_{P70}:3_{20}$
$T_7 = 1_{P100}:3_{20}$ $T_8 = 1_{P100}:3_{30}$
$T_9 = 1_{P100}:4_{20}$ T_{10} = Sole sunflower (50 cm × 25 cm)

1p = one paired rows of maize followed by 70 or 100 cm gap

1:1 = One row of sunflower followed by one row of chickpea

2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings



$T_1 = 1{:}1$ $T_2 = 1{:}2_{20}$ $T_3 = 1_{P70}{:}2_{20}$ $T_4 = 1_{P70}{:}2_{30}$

$T_5 = 1_{P70}{:}2_{40}$ $T_6 = 1_{P70}{:}3_{20}$ $T_7 = 1_{P100}{:}3_{20}$ $T_8 = 1_{P100}{:}3_{30}$

$T_9 = 1_{P100}{:}4_{20}$ T_{10} = Sole sunflower (50 cm × 25 cm)

1p = one paired rows of maize followed by 70 or 100 cm gap
1:1 = One row of sunflower followed by one row of chickpea
2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings

Figure 2. Effect of sunflower-chickpea intercropping under different row and spacing arrangements on weight of 1000 seeds of sunflower (Vertical bar represents SE values)

4.2.11 Seed yield hectare^{-1}

Seed yield of sunflower varied significantly due to different treatments under the trial (Table 5). The highest yield (2.23 t ha^{-1}) was observed from T_{10} [sole sunflower (50 cm × 25 cm)] which was however, statistically identical (2.04 t ha^{-1}and 2.02 t ha^{-1}) to T_5 (1_{p70}:2_{40}) and T_6 (1_{p70}:3_{20}) and the lowest yield (1.53 t ha^{-1}) was found from T_7 (1_{p100}:3_{20}) which was statistically similar (1.57 t ha^{-1} and 1.59) with T_9 (1_{p100}:4_{20}) and T_8 (1_{p100}:3_{30}).

4.2.12 Relative yield

Relative yield of sunflower showed significant differences due to different treatments (Table 5). The highest relative yield (1.00) was recorded from T_{10} [sole sunflower (50 cm × 25 cm)] which was however, statistically identical (0.92 and 0.91) to T_5 (1_{p70}:2_{40}) and T_6 (1_{p70}:3_{20}) and the lowest relative yield (0.69) was found from T_7 (1_{p100}:3_{20}) which was statistically similar (0.71) with T_8 (1_{p100}:3_{30}) and T_9 (1_{p100}:4_{20}). Singh *et al.* (2007) the intercropping recorded significantly higher sunflower-equivalent yield (SEY) and relative yield.

4.3 Yield contributing characters and yield of chickpea

4.3.1 Plant height

Plant height of chickpea differed significantly at 20, 40, 60, 80 DAS and harvest due to different treatments (Table 6). At 20, 40, 60, 80 DAS and harvest the longest plant (12.53, 23.67, 37.00, 43.00 and 45.47 cm) was obtained from T_{11} [sole chickpea (40 cm × 10 cm)] which was statistically similar (11.60 and 11.55 cm, respectively) with T_5 (1_{p70}:2_{40}) and T_6 (1_{p70}:3_{20}) and the shortest plant (10.20, 17.67, 29.93, 33.60 and 36.33 cm), respectively for same days was recorded from T_9 (1_{p100}:4_{20}). Ghosh *et al.* (2006) reported that intercropping helped in improving the soil physical environment, increasing soil microbial activity and restoring organic matter and also had smothering effect on weed, increased plant growth as well as plant height.

Table 6. Effect of sunflower-chickpea intercropping under different row and spacing arrangements on plant height of chickpea

Treatment	Plant height (cm)				
	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T_1	11.30 bc	19.00 b	32.30 b	36.20 b	38.10 b
T_2	11.10 bc	19.00 b	32.00 b	36.13 b	37.90 b
T_3	11.25 bc	19.20 b	32.65 b	37.10 b	38.40 b
T_4	11.40 abc	19.55 b	33.10 b	37.00 b	39.00 b
T_5	11.60 ab	20.20 b	33.75 ab	37.60 b	40.50 b
T_6	11.55 ab	20.00 b	33.20 b	37.20 b	39.20 b
T_7	10.65 bc	18.25 b	31.20 b	35.20 b	37.20 b
T_8	11.00 bc	18.60 b	31.50 b	35.55 b	37.50 b
T_9	10.20 c	17.67 b	29.93 b	33.60 b	36.33 b
T_{11}	12.53 a	23.67 a	37.00 a	43.00 a	45.47 a
SE	0.370	0.882	1.183	1.472	1.628
Significance level	0.05	0.01	0.05	0.05	0.05
CV(%)	5.68	7.82	6.27	6.91	7.24

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

Row and spacing arrangements of sunflower: Chickpea:

$T_1 = 1:1$
$T_2 = 1:2_{20}$
$T_3 = 1_{P70}:2_{20}$
$T_4 = 1_{P70}:2_{30}$
$T_5 = 1_{P70}:2_{40}$
$T_6 = 1_{P70}:3_{20}$
$T_7 = 1_{P100}:3_{20}$
$T_8 = 1_{P100}:3_{30}$
$T_9 = 1_{P100}:4_{20}$
T_{11} = Sole chickpea (40 cm × 10 cm)

1p = one paired rows of maize followed by 70 or 100 cm gap

1:1 = One row of sunflower followed by one row of chickpea

2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings

4.3.2 Number of branches plant^{-1}

Significant variation was observed for number of branches per plant of chickpea at 20, 40, 60, 80 DAS and at harvest due to different treatments (Table 7). At 20, 40, 60, 80 DAS and at harvest the maximum number of branches per plant (2.80, 5.20, 9.00, 13.10 and 14.60) was recorded from T_{11} [sole chickpea (40 cm × 10 cm)] which was followed by T_5 (1_{p70}:2_{40}) and T_6 (1_{p70}:3_{20}) and the minimum number (1.70, 3.75, 6.62, 10.00 and 10.10), respectively for same days was found from T_9 (1_{p100}:4_{20}). Nargis *et al.* (2004) reported that in 100% lentil + 40% wheat gave the highest number of branches per plant (3.25) of lentil.

4.3.3 Dry matter content of leaf

Dry matter content of leaf of chickpea varied significantly for different treatments (Figure 3). The highest dry matter content of leaf (8.65 g) was found from T_{11} [sole chickpea (40 cm × 10 cm)] which was statistically similar (8.24 and 8.20 g) with T_5 (1_{p70}:2_{40}) and T_6 (1_{p70}:3_{20}) and the lowest (7.10 g) from T_9 (1_{p100}:4_{20}).

4.3.4 Dry matter content of stem

Different treatments significantly influenced dry matter content of stem of chickpea (Figure 4). The highest dry matter content of stem (9.80 g) was obtained from T_{11} [sole chickpea (40 cm × 10 cm)] which was closely followed (9.10 and 8.65 g) by T_5 (1_{p70}:2_{40}) and T_6 (1_{p70}:3_{20}) and the lowest (8.04 g) from T_9 (1_{p100}:4_{20}).

4.3.5 Total dry matter content of plant

Different treatments significantly influenced total dry matter content of plant of chickpea (Table 8). The highest total dry matter content of plant (18.45 g) was obtained from T_{11} [sole chickpea (40 cm × 10 cm)] which was closely followed (17.34 g) by T_5 (1_{p70}:2_{40}) and the lowest (15.14 g) from T_9 (1_{p100}:4_{20}).

4.3.6 Weight of 1000 seeds

Weight of 1000 seeds of chickpea showed non-significant differences due to different treatments (Table 8). The maximum weight of 1000 seeds (120.20 g) was found from T_{11} [sole chickpea (40 cm × 10 cm)] and the minimum weight (111.20 g) was obtained from T_9 (1_{p100}:4_{20}).

Table 7. Effect of sunflower-chickpea intercropping under different row and spacing arrangements on number of branches plant^{-1} of chickpea

Treatment	Number of branches plant^{-1}				
	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T_1	1.90 bcde	4.00 cde	7.60 bcd	10.60 b	11.40 bcd
T_2	1.90 bcde	3.90 de	7.55 cd	10.55 b	11.20 bcd
T_3	2.00 bcd	4.00 cde	7.70 bc	10.65 b	11.70 bc
T_4	2.05 bc	4.20 cd	7.70 bc	10.80 b	12.07 bc
T_5	2.10 b	4.60 b	8.10 b	11.20 b	12.20 b
T_6	2.05 bc	4.35 bc	7.80 bc	11.33 b	12.10 b
T_7	1.75 de	3.75 e	7.10 d	10.50 b	10.70 cd
T_8	1.80 cde	3.80 e	7.30 cd	10.30 b	11.00 bcd
T_9	1.70 e	3.75 e	6.62 e	10.00 b	10.10 d
T_{11}	2.80 a	5.20 a	9.00 a	13.10 a	14.60 a
SE	0.079	0.121	0.160	0.454	0.412
Significance level	0.01	0.01	0.01	0.01	0.01
CV(%)	6.84	5.04	9.61	7.21	6.09

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

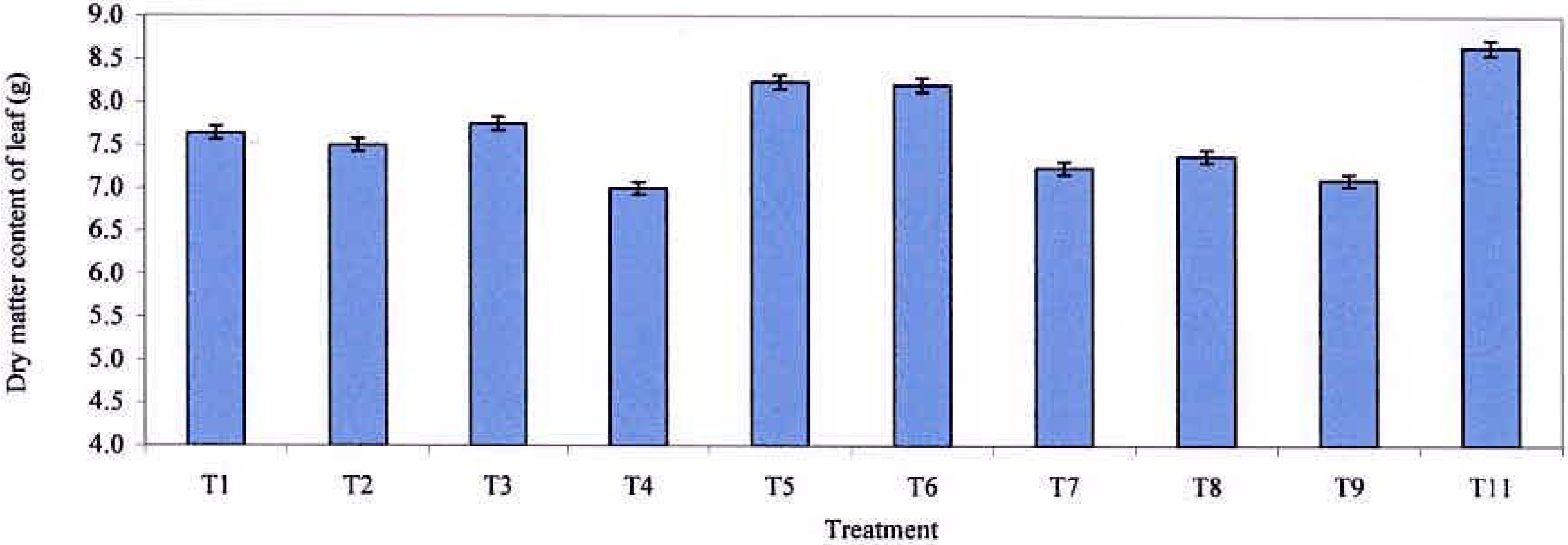
Row and spacing arrangements of sunflower: Chickpea:

$T_1 = 1:1$ | $T_2 = 1:2_{20}$
$T_3 = 1_{P70}:2_{20}$ | $T_4 = 1_{P70}:2_{30}$
$T_5 = 1_{P70}:2_{40}$ | $T_6 = 1_{P70}:3_{20}$
$T_7 = 1_{P100}:3_{20}$ | $T_8 = 1_{P100}:3_{30}$
$T_9 = 1_{P100}:4_{20}$ | T_{11} = Sole chickpea (40 cm × 10 cm)

1p = one paired rows of maize followed by 70 or 100 cm gap

1:1 = One row of sunflower followed by one row of chickpea

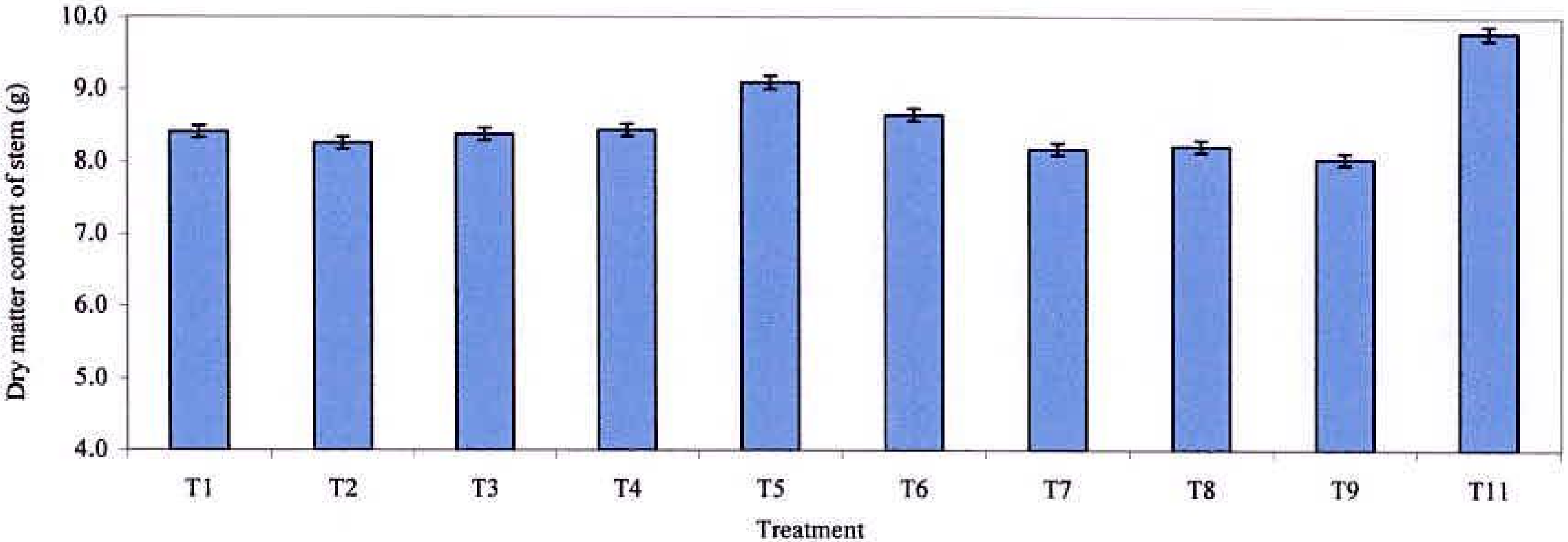
2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings



T_1 = 1:1 | T_2 = $1:2_{20}$ | T_3 = $1_{P70}:2_{20}$ | T_4 = $1_{P70}:2_{30}$
T_5 = $1_{P70}:2_{40}$ | T_6 = $1_{P70}:3_{20}$ | T_7 = $1_{P100}:3_{20}$ | T_8 = $1_{P100}:3_{30}$
T_9 = $1_{P100}:4_{20}$ | T_{11} = Sole chickpea (40 cm × 10 cm)

1p = one paired rows of maize followed by 70 or 100 cm gap
1:1 = One row of sunflower followed by one row of chickpea
2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings

Figure 3. Effect of sunflower-chickpea intercropping under different row and spacing arrangemente on dry matter content of leaf of chickpea (Vertical bar represents SE values)



T_1 = 1:1 T_2 = $1{:}2_{20}$ T_3 = $1_{P70}{:}2_{20}$ T_4 = $1_{P70}{:}2_{30}$
T_5 = $1_{P70}{:}2_{40}$ T_6 = $1_{P70}{:}3_{20}$ T_7 = $1_{P100}{:}3_{20}$ T_8 = $1_{P100}{:}3_{30}$
T_9 = $1_{P100}{:}4_{20}$ T_{11} = Sole chickpea (40 cm × 10 cm)

1p = one paired rows of maize followed by 70 or 100 cm gap
1:1 = One row of sunflower followed by one row of chickpea
2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings

Figure 4. Effect of sunflower-chickpea intercropping under different row and spacing arrangements on dry matter content of stem of chickpea (Vertical bar represents SE values)

4.3.7 Seed yield hectare^{-1}

Statistically significant variation was observed in terms of seed yield of chickpea due to different treatments (Table 8). The highest seed yield (2.42 t ha^{-1}) was recorded from T_{11} [sole chickpea (40 cm × 10 cm)] which was closely followed (2.04 t ha^{-1}) by T_5 (1_{p70}:2_{40}) and the lowest seed yield (1.47 t ha^{-1}) was found from T_9 (1_{p100}:4_{20}). Ylmaz *et al.* (2008) reported that compared to solitary planting, the maize-cowpea and maize-common bean intercropping systems at a 67:50% proportion (plant density) was superior in terms of yield.

4.3.8 Relative yield

Relative yield of chickpea showed significant differences due to different treatments (Table 8). The highest relative yield (1.00) was observed from T_{11} [sole chickpea (40 cm × 10 cm)] which was closely followed (0.84) by T_5 (1_{p70}:2_{40}) and the lowest relative yield (0.61) was found from T_9 (1_{p100}:4_{20}). Xiao *et al.* (2008) reported that intercropping patterns must have harmoniously reasonable population structure, good ventilation and light transmission, resulting in robust growth, good agronomic feature and high relative yield.

3.4 Data on land equivalent ratio, equivalent yield, economic analysis and N, P, K concentration in post harvest soil

3.4.1 Land equivalent ratio

Land equivalent ratio (LER) for sunflower and chickpea intercropping showed significant varaition due to different treatments (Figure 5). The highest LER (1.76) was recorded from T_5 (1_{p70}:2_{40}) which was statistically similar (1.71) with T_6 (1_{p70}:3_{40}) and the lowest LER was recorded from the sole crop both sunflower and chickpea. It revealed that intercropping was highly productive than the sole crop cultivation. Intercropping is also considered as a well recognized practice for better land use system along with substantial yield advantages compared to sole cropping. These advantages may be especially important because they are achieved not by means of costly inputs but also by the simple expedient of growing crops together (Willey, 1979).

Table 8. Effect of sunflower-chickpea intercropping under different row and spacing arrangements on yield contributing characters and yield of chickpea

Treatment	Total dry matter content of plant (g)	Weight of 1000 seeds (g)	Yield (t/ha)	Relative yield
T_1	16.05 d	115.24	1.76 cde	0.73 cde
T_2	15.76 de	115.00	1.72 de	0.71 def
T_3	16.13 cd	116.56	1.88 bcd	0.78 bcd
T_4	15.44 de	117.22	1.96 bc	0.81 bc
T_5	17.34 b	118.34	2.04 b	0.84 b
T_6	16.85 bc	117.32	1.95 bc	0.81 bc
T_7	15.42 de	112.82	1.55 ef	0.64 fg
T_8	15.60 de	113.44	1.61 ef	0.67 efg
T_9	15.14 e	111.20	1.47 f	0.61 g
T_{11}	18.45 a	120.20	2.42 a	1.00 a
SE	0.161	3.752	0.066	0.027
Significance level	0.01	NS	0.01	0.01
CV(%)	7.91	5.61	6.23	6.23

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

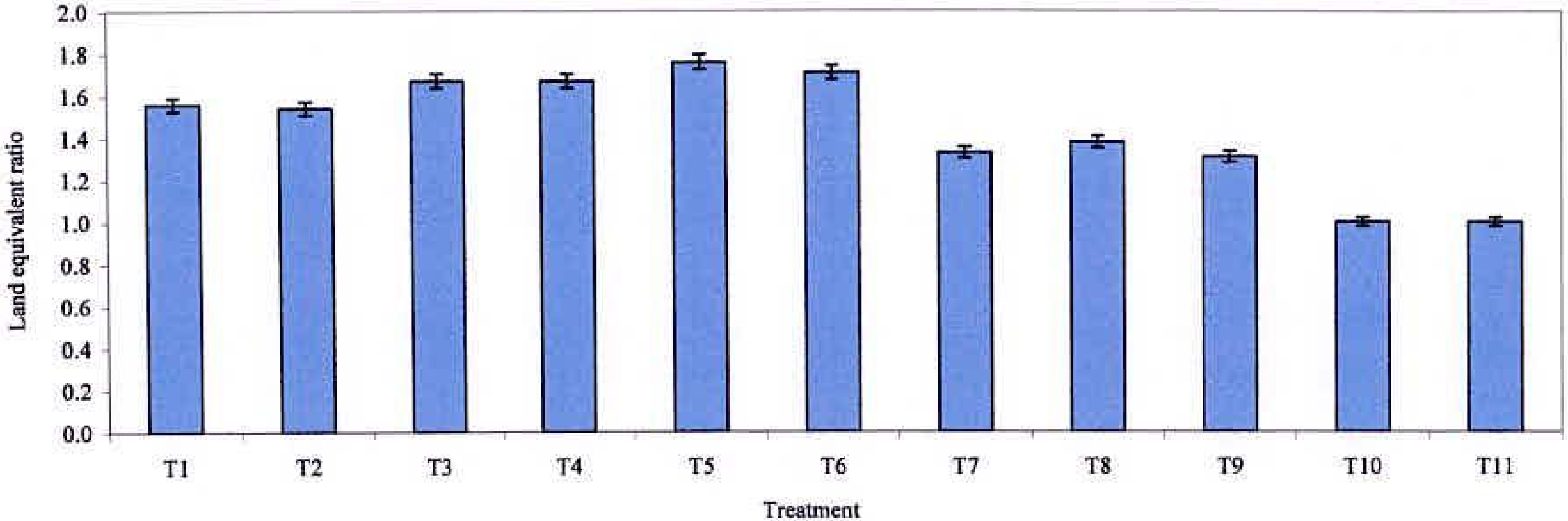
Row and spacing arrangements of sunflower: Chickpea:

T_1 = 1:1
$T_2 = 1:2_{20}$
$T_3 = 1_{P70}:2_{20}$
$T_4 = 1_{P70}:2_{30}$
$T_5 = 1_{P70}:2_{40}$
$T_6 = 1_{P70}:3_{20}$
$T_7 = 1_{P100}:3_{20}$
$T_8 = 1_{P100}:3_{30}$
$T_9 = 1_{P100}:4_{20}$
T_{11} = Sole chickpea (40 cm × 10 cm)

1p = one paired rows of maize followed by 70 or 100 cm gap

1:1 = One row of sunflower followed by one row of chickpea

2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings



$T_1 = 1:1$ $T_2 = 1:2_{20}$ $T_3 = 1_{P70}:2_{20}$ $T_4 = 1_{P70}:2_{30}$

$T_5 = 1_{P70}:2_{40}$ $T_6 = 1_{P70}:3_{20}$ $T_7 = 1_{P100}:3_{20}$ $T_8 = 1_{P100}:3_{30}$

$T_9 = 1_{P100}:4_{20}$ T_{10} = Sole chickpea (40 cm × 10 cm) T_{11} = Sole chickpea (40 cm × 10 cm)

p = one paired rows of maize followed by 70 or 100 cm gap
1:1 = One row of sunflower followed by one row of chickpea
2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings

Figure 5. Effect of sunflower-chickpea intercropping under different row and spacing arrangements on land equivalent ratio (Vertical bar represents SE values)

3.4.2 Equivalent yield

Equivalent yield (EY) of sunflower showed significant variation due to different treatments (Figure 6). The highest EY of sunflower (3.81 t ha^{-1}) was recorded from T_5 (1_{p70}:2_{40}) which was statistically similar (3.71 t ha^{-1}, 3.69 t ha^{-1} and 3.54 t ha^{-1}) with T_6 (1_{p70}:3_{40}), T_3 (1_{p70}:2_{20}) and T_4 (1_{p70}:2_{30}), and the lowest EY of sunflower (2.09 t ha^{-1}) was recorded from the sole crop of chickpea.

Equivalent yield (EY) of chickpea showed significant variation due to different treatments (Figure 6). The highest EY of chickpea (4.39 t ha^{-1}) was recorded from T_5 (1_{p70}:2_{40}) which was statistically similar (4.28 and 4.26 t ha^{-1}) with T_6 (1_{p70}:3_{40}), and T_3 (1_{p70}:2_{20}), and the lowest (2.57 t ha^{-1}) was recorded from the sole crop of sunflower.

It revealed that intercropping was highly productive than the sole crop cultivation. Intercropping is also considered as a well recognized practice for better land use system along with substantial yield advantages. These advantages may be especially important because they are achieved not by means of costly inputs but also by the simple expedient of growing crops together (Willey, 1979).

3.3.3 Combined yield of sunflower and chickpea

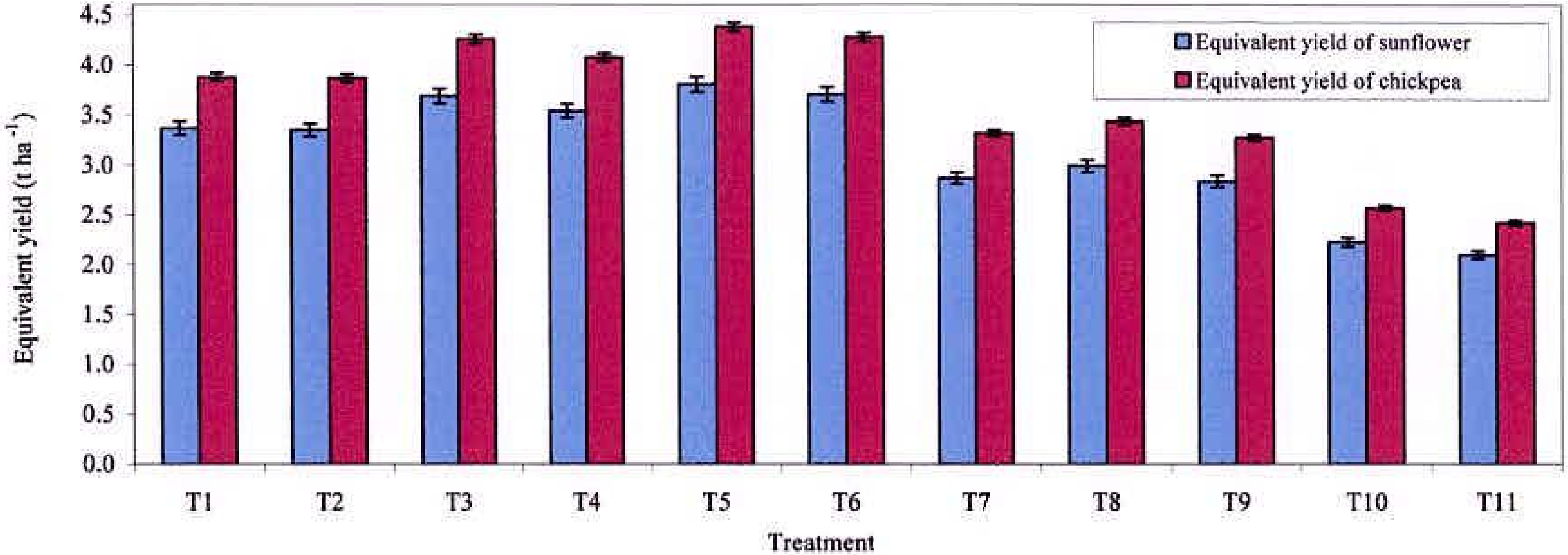
Combined yield of sunflower and chickpea showed significant variation due to different treatments (Figure 7). The highest combined yield of sunflower and chickpea (4.08 t ha^{-1}) was recorded from T_5 (1_{p70}:2_{40}) which was statistically similar (3.97 t ha^{-1}, 3.87 t ha^{-1} and 3.87 t ha^{-1}) with T_6 (1_{p70}:3_{40}), T_3 (1_{p70}:2_{20}) and T_4 (1_{p70}:2_{30}), and the lowest combined yield (2.23 t ha^{-1}) was recorded from the sole crop of sunflower.

3.4.4 Economic analysis

The highest benefit cost ratio (3.52) was recorded from T_5 (1_{p70}:2_{40}) and the second highest benefit cost ratio (3.40) was recorded from T_6 (1_{p70}:3_{40}). On the other hand the lowest benefit cost ratio (1.49) was recorded from the sole crop of chickpea (Table 9).

3.4.5 NPK concentration on soil after crop harvest

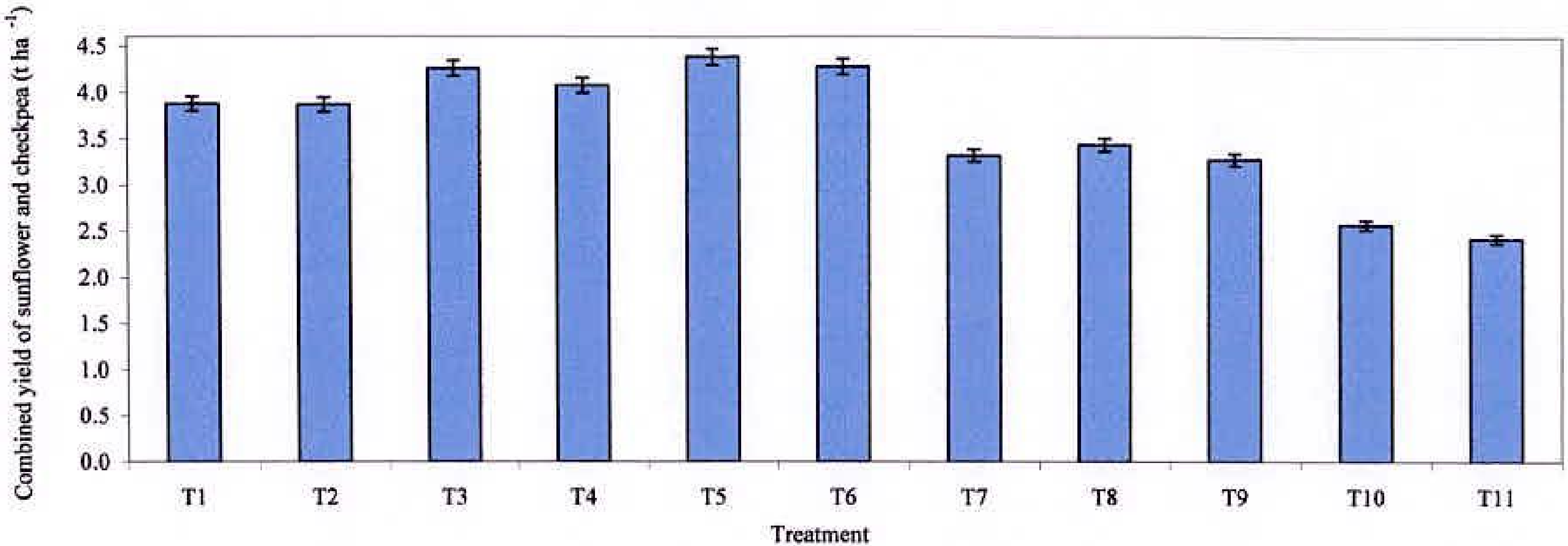
Statistically significant variation was recorded in terms of NPK content in post harvest soil of sunflower and chickpea intercropping for different treatments (Table 10). The maximum N of post harvest soil (0.085%) was recorded from T_6 (1_{p70}:3_{40}) and the minimum N (0.70%) from T_3 (1_{p70}:2_{20}). The maximum P of post harvest soil (7.80 ppm) was recorded from T_7 (1_{p100}:3_{20}) and the minimum P (5.73 ppm) from T_2 (1:2_{20}). The maximum K of post harvest soil (0.32 me%) was found from T_{11} (sole chickpea) and the minimum K (0.26 me%) was observed from T_1 (1:1). It was known that intercropping legumes in sunflower increased soil cover, reduced soil erosion and increased soil carbon and nitrogen (Kandel *et al*., 1997).



T_1 = 1:1 T_2 = $1:2_{20}$ T_3 = $1_{P70}:2_{20}$ T_4 = $1_{P70}:2_{30}$
T_5 = $1_{P70}:2_{40}$ T_6 = $1_{P70}:3_{20}$ T_7 = $1_{P100}:3_{20}$ T_8 = $1_{P100}:3_{30}$
T_9 = $1_{P100}:4_{20}$ T_{10} = Sole chickpea (40 cm × 10 cm) T_{11} = Sole chickpea (40 cm × 10 cm)

p = one paired rows of maize followed by 70 or 100 cm gap
1:1 = One row of sunflower followed by one row of chickpea
2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings

Figure 6. Effect of sunflower-chickpea intercropping under different row and spacing arrangements on equivalent yield (Vertical bar represents SE values)



$T_1 = 1{:}1$ $\quad$ $T_2 = 1{:}2_{20}$ $\quad$ $T_3 = 1_{P70}{:}2_{20}$ $\quad$ $T_4 = 1_{P70}{:}2_{30}$

$T_5 = 1_{P70}{:}2_{40}$ $\quad$ $T_6 = 1_{P70}{:}3_{20}$ $\quad$ $T_7 = 1_{P100}{:}3_{20}$ $\quad$ $T_8 = 1_{P100}{:}3_{30}$

$T_9 = 1_{P100}{:}4_{20}$ $\quad$ T_{10} = Sole chickpea (40 cm × 10 cm) $\quad$ T_{11} = Sole chickpea (40 cm × 10 cm)

p = one paired rows of maize followed by 70 or 100 cm gap
1:1 = One row of sunflower followed by one row of chickpea
2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings

Figure 7. Effect of sunflower-chickpea intercropping under different row and spacing arrangements on combined yield of sunflower and chickpea (Vertical bar represents SE values)

Table 9. Economic analysis sunflower-chickpea intercropping under different row and spacing arrangements

Treatment	Cost of Management (Tk./ha)					Cost of land and miscellaneous (Tk.)	Total cost Tk.ha)	Yield of sunflower (t/ha)	Yield of chickpea (t/ha)	Gross return (tk./ha)	Net return (Tk.ha)	Benefit cost ratio
	Land preparation	Seed	Fertilizer	Labor	Irrigation							
T_1	8000	4000	8550	11000	5000	14000	50550	1.86	1.76	203120	152570	3.02
T_2	8000	4000	8550	11000	5000	14000	50550	1.84	1.72	199840	149290	2.95
T_3	8000	4000	8550	11000	5000	14000	50550	1.99	1.88	217160	166610	3.30
T_4	8000	4000	8550	11000	5000	14000	50550	1.91	1.96	216520	165970	3.28
T_5	8000	4000	8550	11000	5000	14000	50550	2.04	2.04	228480	177930	3.52
T_6	8000	4000	8550	11000	5000	14000	50550	2.02	1.95	222600	172050	3.40
T_7	8000	4000	8550	11000	5000	14000	50550	1.53	1.55	172400	121850	2.41
T_8	8000	4000	8550	11000	5000	14000	50550	1.59	1.61	179120	128570	2.54
T_9	8000	4000	8550	11000	5000	14000	50550	1.57	1.47	170640	120090	2.38
T_{10}	8000	4000	8550	11000	5000	14000	50550	2.23	0	133800	83250	1.65
T_{11}	8000	4000	8550	11000	5000	14000	50550	0	2.42	125840	75290	1.49

Price: Seeds of sunflower @ Tk. 60/kg; Seeds of chickpea @ Tk. 52/kg; Fertilizer- Urea @ Tk. 8/kg, MP @ Tk. 15/kg, TSP @ Tk. 18/kg, $ZnSo_4$ @ Tk. 65/kg, Zypsum @ Tk. 35/kg and Labour @ Tk. 150/day/man

Row and spacing arrangements of sunflower: Chickpea:

T_1 = 1:1 $T_2 = 1:2_{20}$

$T_3 = 1_{P70}:2_{20}$ $T_4 = 1_{P70}:2_{30}$

$T_5 = 1_{P70}:2_{40}$ $T_6 = 1_{P70}:3_{20}$

$T_7 = 1_{P100}:3_{20}$ $T_8 = 1_{P100}:3_{30}$

$T_9 = 1_{P100}:4_{20}$ T_{10} = Sole sunflower (50 cm × 25 cm)

T_{11} = Sole chickpea (40 cm × 10 cm)

1p = one paired rows of maize followed by 70 or 100 cm gap

1:1 = One row of sunflower followed by one row of chickpea

2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings

Table 10. Effect of sunflower-chickpea intercropping under different row and spacing arrangements on N, P, K in post harvest soil

Treatment	N (%)	P (ppm)	K (me%)
T_1	0.084 ab	6.57 bcd	0.27 d
T_2	0.075 c	5.73 d	0.27 d
T_3	0.070 d	6.87 abcd	0.29 bc
T_4	0.078 bc	7.30 ab	0.28 bcd
T_5	0.067 d	6.10 cd	0.29 ab
T_6	0.085 a	7.27 abc	0.28 bcd
T_7	0.079 abc	7.80 a	0.27 cd
T_8	0.083 ab	6.63 bcd	0.31 a
T_9	0.083 ab	6.57 bcd	0.28 bcd
T_{10}	0.084 ab	6.60 bcd	0.27 d
T_{11}	0.076 c	6.53 bcd	0.32 a
SE	0.003	0.348	0.010
Significance level	0.01	0.05	0.05
CV(%)	7.30	8.95	6.02

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

Row and spacing arrangements of sunflower: Chickpea:

$T_1 = 1:1$
$T_2 = 1:2_{20}$
$T_3 = 1_{P70}:2_{20}$
$T_4 = 1_{P70}:2_{30}$
$T_5 = 1_{P70}:2_{40}$
$T_6 = 1_{P70}:3_{20}$
$T_7 = 1_{P100}:3_{20}$
$T_8 = 1_{P100}:3_{30}$
$T_9 = 1_{P100}:4_{20}$
T_{10} = Sole sunflower (50 cm × 25 cm)
T_{11} = Sole chickpea (40 cm × 10 cm)

1p = one paired rows of maize followed by 70 or 100 cm gap

1:1 = One row of sunflower followed by one row of chickpea

2, 3, 4 are number of chick pea rows in 70 or 100 cm gap with 20, 30 or 40 cm spacings

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted at the experimental field of Agronomy Department Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from November 2008 to March 2009 to find out the effect of intercropping chickpea with sunflower under different row and spacing arrangements. Seeds of sunflower variety DS-1 (Kironi) and Chickpea variety BARI Chola-5 used as a test crop for the study. The experiment consisted of nine row arrangement combination of sunflower and chickpea plus the sole of both crops. The row arrangement of sunflower were recommended (50 cm apart), paired rows (30 cm apart) followed by 70 cm gap and paired rows followed by 100 cm gap. In the recommended rows arrangement 1-2 rows of chickpeas were accommodated, while within the gap between two paired rows 1-4 rows of chickpeas were accommodated. The experiment was laid out in Randomized Complete Block Design (BCBD) with three replications. Data on soil moisture, light intensity, growth parameter, yield attributes and yield were recorded for sunflower and chickpea. Land equivalent ratio, equivalent yield and N, P, K also estimated in post harvest soil.

Soil moisture and light intensity of the sunflower and chickpea intercropped field showed significant variation. At 20, 40, 60 and 80 DAS the maximum soil moisture (32.62%, 31.10%, 34.18% and 35.20%) was recorded from T_5 and, at the same DAS the minimum (26.25%, 25.10%, 27.00% and 27.60%), respectively was recorded from T_{10}. In case of sunflower, the maximum light intensity (287.00 Lx) was observed from T_2 and the minimum (281.00 Lx) was recorded from T_9. In case of chickpea, the maximum light intensity (287.33 Lx, 285.00 Lx and 284.33 Lx) was recorded from T_{11} at the point of upper, middle and basement of the plant, respectively, while the minimum (167.00 Lx, 147.00 Lx and 125 Lx) was found from T_9 at the same position.

Significant difference was recorded for yield contributing characters and yield of sunflower. At 20, 40, 60, 80 DAS and at harvest the longest plant (21.70, 55.00, 77.83, 98.20 and 112.67 cm) was obtained from T_{10} and the shortest plant (16.50, 46.13, 62.60, 84.00 and 100.33 cm), respectively for same days was recorded from T_9. The highest leaf area (241.67 cm^2) was observed from T_{10} and the lowest leaf area (214.00 cm^2) was found from T_9. The highest head diameter of sunflower (12.42 cm) was found from T_{10} but the lowest head diameter of sunflower (10.05 cm) was recorded from T_9. The maximum filled grains of sunflower (277.00) were recorded from T_{10} and the minimum (241.00) was obtained from T_9. The minimum unfilled grains of sunflower (55.10) were recorded from T_{10} and the maximum (69.50) from T_9. The maximum total grains of sunflower (332.10) were observed from T_{10} and the minimum (310.50) from T_9. The maximum dry matter content of leaf (8.22 g) was found from T_{10} and the minimum (7.54 g) was obtained from T_9. The maximum dry matter of stem (9.64 g) was recorded from T_{10} and the minimum (8.52 g) was found from T_9. The maximum total dry matter content of plant (17.86 g) was recorded from T_{10} and the minimum (16.06 g) from T_9. The highest weight of 1000 seeds of sunflower (65.20 g) was found from T_{10} and the lowest weight (60.80 g) from T_9. The highest yield (2.23 t ha^{-1}) was observed from T_{10} and the lowest (1.53 t ha^{-1}) from T_7. The highest relative yield (1.00) was recorded from T_{10} and the lowest (0.69) from T_7.

Significant difference was recorded for yield contributing characters and yield of chickpea. At 20, 40, 60, 80 DAS and harvest the longest plant (12.53, 23.67, 37.00, 43.00 and 45.47 cm) was obtained from T_{11} and the shortest plant (10.20, 17.67, 29.93, 33.60 and 36.33 cm) from T_9. At 20, 40, 60, 80 DAS and harvest the maximum number of branches per plant (2.80, 5.20, 9.00, 13.10 and 14.60) was recorded from T_{11} and the minimum number (1.70, 3.75, 6.62, 10.00 and 10.10), respectively for same days from T_9. The highest dry matter content of leaf (8.65 g) was found from T_{11} and the lowest (7.10 g) from T_9. The highest dry matter content of stem (9.80 g) was obtained from T_{11} and the lowest (8.04 g) from T_9. The highest total dry matter content of plant (9.80 g) was obtained from T_{11} and the lowest (8.04 g) from T_9. The maximum weight of 1000 seeds (120.20 g) was found from T_{11} and the minimum weight (111.20 g) from T_9. The highest seed yield (2.42 t ha^{-1}) was recorded from T_{11} and the lowest (1.47 t ha^{-1}) from T_9. The highest relative yield (1.00) was observed from T_{11} and the lowest (0.61) from T_9.

The highest LER (1.76) was recorded from T_5 and the lowest LER from the sole crop both sunflower and chickpea. The highest equivalent yield (EY) of sunflower (3.81 t ha^{-1}) was recorded from T_5 and the lowest (2.09 t ha^{-1}) from the sole crop of chickpea. The highest EY of chickpea (4.39 t ha^{-1}) was recorded from T_5 and the lowest (2.57 t ha^{-1}) from the sole crop of sunflower. The highest combined yield of sunflower and chickpea (4.08 t ha^{-1}) was recorded from T_5 and the lowest (2.23 t ha^{-1}) from the sole crop of sunflower. The highest benefit cost ratio (3.52) was recorded from T_5 and the lowest (1.49) from the sole crop of chickpea. The maximum N of post harvest soil (0.085%) was recorded from T_6 and the minimum N (0.70%) from T_3. The maximum P (7.80 ppm) was recorded from T_7 and the minimum P (5.73 ppm) from T_2. The maximum K of post harvest soil (0.32 me%) was found from T_{11} and the minimum K (0.26 me%) from T_1.

Among the nine row arrangement combination of sunflower and chickpea plus the sole of both crops, $1_{P70}:2_{40}$ row arrangement, sunflower was sown in paired rows maintaining row to row distance of 30 cm and two rows of chickpea were sown at the middle space of 70 cm between paired sunflower rows maintaining chickpea row to row distance of 40 cm was more effective arrangement as intercrop of sunflower and chickpea in context of growth parameter, yield, land equivalent ratio, equivalent yield.

Considering the results of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed to be repeated in different agro-ecological zones (AEZ) of Bangladesh for the evaluation of regional adaptability;
2. Another row and spacing arrangement and different crop may be included in the future study.

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APPENDICES

Appendix I*. Characteristics of experimental field soil

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

I*- Analyzed by Soil Resources Development Institute (SRDI), Khamarbari Road, Farmgate, Dhaka

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Appendix II. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from October 2008 to March, 2009

Month	*Air temperature (°C)		*Relative humidity (%)	*Rainfall (mm) (total)
	Maximum	Minimum		
October, 2008	29.18	18.26	81	39
November, 2008	25.82	16.04	78	00
December, 2008	22.4	13.5	74	00
January, 2009	24.5	12.4	68	00
February, 2009	27.1	16.7	67	30
March, 2009	31.4	19.6	54	11

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix III. Analysis of variance of the data on soil moisture content in the field as influenced by sunflower-chickpea intercropping under different row and spacing arrangements

Source of variation	Degrees of freedom	Mean square			
		Soil moisture (%)			
		20 DAS	40 DAS	60 DAS	80 DAS
Replication	2	1.211	1.304	0.383	0.628
Treatment	10	119.069*	12.073**	17.188**	17.620**
Error	20	97.738	2.804	4.478	5.244

**: Significant at 0.01 probability; *: Significant at 0.05 probability

Appendix IV. Analysis of variance of the data on light intensity in the field as influenced by sunflower-chickpea intercropping under different row and spacing arrangements

Source of variation	Degrees of freedom	Mean square			
		Light intensity (Lux)			
		Sunflower	Chickpea		
			Upper	Middle	Base
Replication	2	36.273	23.394	2.545	2.303
Treatment	10	11.891	6441.90**	4726.70**	6469.67**
Error	20	58.273	63.261	49.779	55.336

**: Significant at 0.01 probability

Appendix V. Analysis of variance of the data on plant height of sunflower as influenced by sunflower-chickpea intercropping under different row and spacing arrangements

Source of variation	Degrees of freedom	Mean square				
		Plant height of sunflower at				
		20 DAS	40 DAS	60 DAS	80 DAS	Harvest
Replication	2	0.016	4.632	0.660	1.156	19.900
Treatment	9	7.348*	23.735**	55.538*	56.163**	41.985*
Error	18	2.383	6.948	21.627	16.374	15.530

**: Significant at 0.01 probability; *: Significant at 0.05 probability

Appendix VI. Analysis of variance of the data on leaf area at 90 DAS and yield contributing characters of sunflower as influenced by sunflower-chickpea intercropping under different row and spacing arrangements

Source of variation	Degrees of freedom	Mean square				
		Leaf area at 90 DAS	Number of filled grains $plant^{-1}$	Number of unfilled grains $plant^{-1}$	Total number of grains $plant^{-1}$	Head diameter (cm)
Replication	2	32.933	28.900	2.019	26.839	0.183
Treatment	9	204.389*	380.000*	53.060**	168.660	1.235**
Error	18	67.600	140.011	11.226	175.957	0.351

**: Significant at 0.01 probability; *: Significant at 0.05 probability

Appendix VII. Analysis of variance of the data on yield contributing characters and yield of sunflower as influenced by sunflower-chickpea intercropping under different row and spacing arrangements

Source of variation	Degrees of freedom	Mean square					
		Dry matter content of leaf (g)	Dry matter content of stem (g)	Total dry matter content of plant (g)	Weight of 1000 seeds (g)	Yield (t/ha)	Relative yield
Replication	2	0.017	0.035	0.009	0.775	0.010	0.002
Treatment	9	0.153*	0.364**	0.968**	4.248	0.159**	0.032**
Error	18	0.054	0.083	0.179	9.454	0.016	0.003

**: Significant at 0.01 probability; *: Significant at 0.05 probability

Appendix VIII. Analysis of variance of the data on plant height of chickpea as influenced by sunflower-chickpea intercropping under different row and spacing arrangements

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm)				
		20 DAS	40 DAS	60 DAS	80 DAS	Harvest
Replication	2	0.340	0.939	1.097	2.986	4.764
Treatment	9	1.144*	8.142**	10.662*	18.168*	19.691*
Error	18	0.410	2.331	4.195	6.496	7.949

**: Significant at 0.01 probability; *: Significant at 0.05 probability

Appendix IX. Analysis of variance of the data on number of branches plant^{-1} of chickpea as influenced by sunflower-chickpea intercropping under different row and spacing arrangements

Source of variation	Degrees of freedom	Mean square				
		Number of branches plant^{-1}				
		20 DAS	40 DAS	60 DAS	80 DAS	Harvest
Replication	2	0.003	0.012	0.036	0.102	0.152
Treatment	9	0.289**	0.632**	1.186**	2.244**	4.448**
Error	18	0.019	0.044	0.076	0.618	0.509

**: Significant at 0.01 probability

Appendix X. Analysis of variance of the data on yield contributing characters and yield of chickpea as influenced by sunflower-chickpea intercropping under different row and spacing arrangements

Source of variation	Degrees of freedom	Mean square					
		Dry matter content of leaf (g)	Dry matter content of stem (g)	Total dry matter content of plant (g)	Weight of 1000 seeds (g)	Yield (t/ha)	Relative yield
Replication	2	0.069	0.011	0.113	0.532	0.007	0.001
Treatment	9	0.882**	0.842**	3.224**	22.408	0.233**	0.040**
Error	18	0.076	0.104	0.188	42.223	0.013	0.002

**: Significant at 0.01 probability

Appendix XI. Analysis of variance of the data on land equivalent ratio, equivalent yield of sunflower and chickpea, N, P, K in post harvest soil as influenced by sunflower-chickpea intercropping under different row and spacing arrangements

Source of variation	Degrees of freedom	Mean square					
		Land equivalent ratio	Equivalent yield of sunflower	Equivalent yield of chickpea	N (%)	P (ppm)	K (me%)
Replication	2	0.005	0.003	0.005	0.0001	0.091	0.0001
Treatment	10	0.217**	1.030**	1.370**	0.001**	0.985*	0.001*
Error	20	0.009	0.021	0.027	0.0001	0.362	0.0001

**: Significant at 0.01 probability; *: Significant at 0.05 probability