PERFORMANCE OF WHEAT – LENTIL MIXED CROPPING UNDER DIFFERENT SEED RATE RATIO

BY

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CERTIFICATE

This is to certify that the thesis entitled, "**PERFORMANCE OF WHEAT – LENTIL MIXED CROPPING UNDER DIFFERENT SEED RATE RATIO.**" Submitted to the Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment 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 **MOHAMMAD MALEK**, Registration No. 00697 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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Dedicated to
My
Beloved Parents

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The Author

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ABSTRACT

An experiment on the performance of wheat – lentil mixed cropping under different seed rates of both wheat and lentil (100%, 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20% and 10%, respectively) was conducted at the Agronomy Field, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November, 2006 to March, 2007. The experiment was laid out in a randomized complete block design with three replications. Results showed that significantly higher yields of wheat (3.14, 2.92, 2.88 and 2.84 t ha^{-1}, respectively) were obtained with the treatment of sole wheat, wheat 90% + lentil 10%, wheat 80% + lentil 20% and wheat 70% + lentil 30%. Significantly the highest combined yield of 3.21 t ha^{-1} was obtained with the treatment of wheat 70% + lentil 30%. The highest land equivalent ratio, benefit-cost ratio and total net return of 1.30, 2.14 and Tk. 61026.75 ha^{-1}, respectively were obtained with the treatment of wheat 70% + lentil 30%. It was concluded that lentil may be intercropped with wheat using the combination of 70% wheat seed rate + 30% lentil seed rate.

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

Chapter 1
Introduction

CHAPTER 1

Introduction

Bangladesh is an agriculture based country. Most of the people of this country are involved with this activity. The land area of this country is very limited compared to it's large population. Increasing agricultural production per unit area of land is becoming most important step to cope with the present population growth in Bangladesh. In recent years, multiple cropping has been gaining importance as a means of more crop production in limited land area particularly in the countries with small size farm holdings.

Intercropping is a conception of a great production per unit area for the compensation of land decreasing causes. By the practice of intercropping system, people can improve their socio-economic condition of their family. All the intercropping systems give substantially higher total yield equivalent than that of the sole crop (Nazir *et al.*, 1997).

Wheat (*Triticum aestivum* L) is the first on cereal grain crop of the world but in Bangladesh, it is the second important cereal crop next to rice. Rice is mainly cultivated as a principal food crop but wheat is also an another main food crop which contribute more than 15.2 percent of the staple cereal food of this country (BBS, 2005). Wheat cultivated land area in Bangladesh was about 556.00 thousand hectares and the total production was 1050.2 thousand m tons with an average yield of 1.89 t ha^{-1} in 2004 -2005 (BBS, 2005).

Lentil (*Lens esculentus*) is a popular pulse crop and it is known in our Bangladesh as musur. It is the most widely grown pulse crop. According to the total production it covers second position in our country. Lentil covers 2.07 lac hectare land with a production of 1 lac and 70 thousand m ton (BARI, 2005).

For wheat cultivation, the climatic condition of Bangladesh is favorable. It is well adapted in Bangladesh climate and only grows in winter season. It contains about 12.1% protein, 69.60% carbohydrate, 1.72% fat, 27.60% minerals and a good source of vitamin B complex (Anon, 1997). The crop is grown under different environmental condition ranging from humid to arid, sub-tropical to temperate zone (Saari, 1998).

Bangladesh grows various types of pulse crops. Among which grasspea, lentil, mungbean, blackgram, fieldpea, cowpea etc. are important. These crops provide valuable protein in human diet. Lentil is a protein rich pulse crop and it contains 24- 28% protein. According to FAO (1999) recommendation, a minimum intake of pulse per capita should be 8o g day^{-1}, where it is only 12 g day^{-1} in Bangladesh. This is because of fact that national total production of pulses is not adequate to meet national demand.

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 *et al.*, 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).

Practicing intercropping lentil with wheat, farmers can obtain wheat and pulse at the same time from the same land. Higher equivalent yields are obtained with intercropping. Land equivalent ratio (LER) values are obtained with intercropping (Sarno *et al.*, 1998).

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).

If lentil is cultivated with a cereal crop like wheat as a mixed crop, farmer may be benefited in three ways; they may get wheat and lentil grain and at the same time soil fertility can be improved by fixing atmospheric nitrogen through formation of root nodule by *Rhizobium bacteria.*

According to Dey and Singh (1981), the most important advantages of such cropping system are;

Insurance against total crop failure under aberrant weather conditions or pest epidemics,

1. Increase in total productivity per unit land area and

2. Equitable and judicious utilization of land resources and farming inputs including labor.

Yields of the component crops in mixed cropping may be influenced by seed rate. With this point in mind, an experiment was conducted with the following objectives:

1. to evaluate the productivity and performance of wheat and lentil under mixed cropping condition.
2. to increase in the total productivity per unit land area.

Chapter 2

Review of literature

CHAPTER 2

Review of Literature

An attempt has been made in this chapter to present a brief review of research in relation to mixed or intercropping of pulse crops with wheat to obtain better yield.

Intercropping is an age old practice and it has been recognized as a very common practice throughout the developing tropics (Willey, 1979).

IRRI (1973) expressed that it 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 gives higher total production; monetary returns and greater resource use and increase the land productivity by almost 60 percent.

Singh (1979, 1983) reported that the degree of complementary (temporal as well as spatial) needs to be maximized by way of differences in growth rhythm, duration, light, nutrient supply and water requirements for maximization of intercropping advantages.

Razzaque (1980) reported that the intercropping experiment on wheat, gram, lentil and mustard 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.

Kalra and Gangwar (1980) and Hashem (1983) experimented to determine the profitability of intercropping systems; agronomically feasible technology may not always be accepted if it is not economically viable. It is claimed that in almost all cases intercropping gave more monetary return than the sole crops.

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.

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.

Islam *et al.* (1982) estimated that 80 per cent N fetilizer 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}.

Hashem (1983) indicated that 40 per cent N may be saved in a maize cowpea intercropping system.

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.

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.

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 pigeon pea resulting an increase in LER by 1.26.

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.

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.

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 soil moisture from deeper soil layers. In intercropping of maize with cowpeas in both dry and rainy season cowpea gave the best result with respect to soil improvement and weed control. 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.

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.

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.

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 wheat 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 4:2 wheat/French bean intercrop (4:2).

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.

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 ratios of wheat: chickpeas), the 2:2 row ratios allowed more light interception and transmission to the lower canopy and gave significantly higher yield (4.16 t ha^{-1} wheat equivalent) and land equivalent ratio (LER) than the other treatments. Fertilizers rates used were those of the recommended ones (120 kg N + 26.4 kg P + 50 kg K ha^{-1}) in both cases.

Patel *et al.* (1984) and 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 manures. 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 rates of nitrogen.

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 patterns 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 crops 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.

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 ratios 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.

Singh (1996) conducted a field trials where wheat and lentil were grown alone or intercropped in 1:1, 1:2, 2:1 or 2:2 row ratios and crops were given 0 - 75 kg N ha^{-1}. Wheat and lentil yields were highest in their sole crops. However, wheat productivity/row was higher when intercropped than when grown alone.

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 in wheat grown alone and in the 2:1 wheat : gram intercrop. Land equivalent ratios were always more than one in most intercropping treatments.

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.

Ghosh *et al.* (1997) conducted a field experiment to study the performance of wheat and lentil. The crops were grown in pure stands or intercropped under different levels of irrigation. Results revealed that mean wheat grain yield was 2.08 t ha^{-1} without irrigation, 2.99 t ha^{-1} with two irrigations (21 and 65 days after sowing) and 3.40 t ha^{-1}

with irrigation at 4 critical growth stages. Lentil yield was 0.68 t ha^{-1} without irrigation, 1.16 t ha^{-1} with two irrigations at branching and flowering, and 0.94 t with 4 irrigations.

Nazir, *et al.* (1997) reported all the intercropping systems were to 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 or 3:2 row ratios. Seed yields of all crops were decreased by intercropping. Total plant N content was highest in *L. culinaris* grown alone. Increasing N fertilizer rate (0 - 90 kg N ha^{-1}) increased wheat grain yield but did not generally affect legume seed yields.

Alam *et al.* (1997) reported that practicing wheat and pulse intercropping reduced the total weed population significantly compared to the wheat monoculture.

Verma *et al.* (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}.

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.

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

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

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.

Ahmad *et al.* (1998) conducted a field experiment in Pakistan. Wheat and lentil were grown alone or intercropped in 80 cm X 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 intercrop. This treatment produced lentil seed yield of 424 kg ha^{-1}. The 8:3 intercrop 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 intercrop.

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

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.

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 (2002) 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.

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.

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.

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

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

Nargis, *et al*. (2004) reported that the increased land equivalent ratio (LER) from a series of experiments on mixed cropping or intercropping indicated that the mixed cropping/intercropping increases the productivity per unit area compared to sole crop. Mixed cropping or intercropping system increased benefit-cost ratio which was found to be remarkably significant.

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%).

Nargis *et al*. (2004) reported that the highest seed yield (2704 kg ha^{-1}) was obtained under line sowing of sole wheat. The variation in the number of effective tillers per plant and number of seeds per plant was not significant. In both crops, line sowing was superior over broadcasting. The higher land equivalent ratio indicated that mixed cropping or intercropping increased the productivity per unit area compared to sole cropping of lentil.

Ahlawat *et al*. (2005) conducted an experiment and found that chickpea yield was adversely affected by intercropping with Indian mustard, barley and linseed. Chickpea yield increased as the proportion of chickpea in the mixture increased from 2:1 to 4:1. Sole Indian mustard productivity, as measured in chickpea equivalent yield was highest, followed by chickpea + Indian mustard (2:1). Chickpea + linseed and sole chickpea recorded similar CEY.

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.

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.

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%.

Chapter 3
Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

In this chapter, the details of different materials used and methodology followed during the experimental period are described.

3.1 Experimental Site

The study was carried out at the Agronomy research farm of Sher-e-Bangla Agricultural University (SAU) during the period from November, 2006 to March, 2007. The soil of the submitted site was medium highland and well drained. Physical and chemical properties of soil and climatic condition (monthly) during the experimental period have been plotted in Appendix I and Appendix II.

3.2 Planting materials

The wheat variety Kanchan and lentil variety BARI musur -3 were used as experimental planting materials. The recommended optimum growing period of the wheat variety was mid-November to mid-March. From sowing to harvesting it was reported to take 106 - 112 days (BARI, 2005).

BARI musur -3 was a recent developed lentil variety which was introduced by BARI in 1984. The seed size of this variety was 40 - 50% larger than the local ones. From sowing to harvesting it was reported to take 100 - 105 days (BARI, 2005).

3.3 Experimental details

3.3.1 Treatments

Twelve treatments were included in the study as follows:

i. T_1 = Sole wheat with recommended seed rate (W_{100}).

ii. T_2 = Sole lentil with recommended seed rate (L_{100}).

iii. T_3 = 90% wheat seed rate and 10% Lentil seed rate ($W_{90} L_{10}$).

iv. T_4 = 80% wheat seed rate and 20% Lentil seed rate ($W_{80} L_{20}$).

v. T_5 =70% wheat seed rate and 30% Lentil seed rate ($W_{70} L_{30}$).

vi. T_6 = 60% wheat seed rate and 40% Lentil seed rate ($W_{60} L_{40}$).

vii. T_7 = 50% wheat seed rate and 50% Lentil seed rate ($W_{50} L_{50}$).

viii. T_8 = 40% wheat seed rate and 60% Lentil seed rate ($W_{40} L_{60}$).

ix. T_9 = 30% wheat seed rate and 70% Lentil seed rate ($W_{30} L_{70}$).

x. T_{10} = 20% wheat seed rate and 80% Lentil seed rate ($W_{20} L_{80}$).

xi. T_{11} = 10% wheat seed rate and 90% Lentil seed rate ($W_{10} L_{90}$).

xii. T_{12} = 100% wheat seed rate and 100% Lentil seed rate ($W_{100} L_{100}$).

3.3.2 Experimental design

The experiment was laid out in a randomized complete block design (RCBD) with three replications. Twelve treatments were randomly assigned in each replication. There were 36 unit plots in the experiment and the size of each unit plot was 3.0 m x 4.0 m.

3.3.3 Land preparation

The land was first ploughed on 4 November, 2006 by disc plough. It was then harrowed again on 11 and 13 November to bring the soil in a good tilth condition. The final land preparation was done by disc harrow on 15 November, 2006. The land was prepared thoroughly and leveled by a ladder. Weeds and stubbles were removed from the field. The experiment was laid out on November 18, 2006 according to the design adopted.

3.3.4 Fertilizer application

Plots having wheat were treated with recommended fertilizer dose of wheat as follows:

Compost	=	8000 – 10000 Kg ha^{-1}
Urea	=	180 Kg ha^{-1}
TSP	=	140 Kg ha^{-1}
MP	=	40 Kg ha^{-1}
Gypsum	=	110 Kg ha^{-1}

Likewise, plots having sole lentil were treated with recommended fertilizer dose of lentil as follows:

Compost	=	4000 – 5000 Kg ha^{-1}
Urea	=	50 Kg ha^{-1}
TSP	=	90 Kg ha^{-1}
MP	=	40 Kg ha^{-1}

Two third ($^2/_3$) amount of urea, whole amount of TSP and MP were applied at the time of final land preparation. Rest amount of urea ($^1/_3$) were applied as top dressing at the time of 1^{st} irrigation.

3.3.5 Sowing of seeds

Seeds were sown by hand on November 18, 2006. Wheat seeds and lentil seeds were mixed proportionately according to the treatment and sown by broadcasting method. Seeds were then covered properly with soil. A wheat seed was required 120 kg ha^{-1} and lentil seeds rate was 35 kg ha^{-1}, respectively.

3.3.6 Intercultural operations

3.3.6.1 Irrigation

Light irrigations were done at alternate days after sowing till emergence. Two flood irrigations were done at 21 and 30 DAS, (Days after sowing) respectively.

3.3.6.2 Weeding

Three weedings were done at 15, 30 and 45 DAS, respectively.

3.3.6.3 Pesticide

The crop field was treated with Malathion @ 22.2 mm/10 liters of water two times and 2% zinc sulphide also two times to control pest.

3.3.7 Harvesting

Lentil was harvested on March 9, 2007 and wheat was harvested on March 27, 2007 plot wise when both crops were reached at the proper maturity stage.

3.4 Recording of data

The following data were recorded from the experiment

3.4.1 Wheat

i. Plant height (cm)
ii. Plant population of wheat
iii. Number of spikes $plant^{-1}$
iv. Spike length of wheat (cm)
v. Number of tillers $plant^{-1}$
vi. Grain weight $spike^{-1}$ (g)
vii. Dry weight $(g\ plant)^{-1}$
viii. Weight of 1000-seeds (g)
ix. Grain yield ($t\ ha^{-1}$)
x. Harvest Index (%)

3.4.2 Lentil

i. Plant height (cm)
ii. Plant population of lentil
iii. No. of branches $plant^{-1}$
iv. Dry weight $plant^{-1}$ (g)
v. No. of pods $plant^{-1}$
vi. Pod weight $plant^{-1}$
vii. Weight of 1000-seeds (g)
viii. Grain yield ($t\ ha^{-1}$)
ix. Harvest Index (%)

3.5 Procedure of recording data

The detail outline of data recording is given below

3.5.1 Wheat

3.5.1.1 Plant height (cm)

The height of five plants were measured from the ground level to tip of the plants and then averaged. It was taken at different days after sowing (30, 60, 90 DAS and at harvest) separately.

3.5.1.2 Number of spikes plant^{-1}

Total number of spikes were counted from five plants and then averaged. It was taken at different days after sowing (80 DAS and at harvest) separately.

3.5.1.3 Spike length (cm)

Spike length were measured from five plants and then averaged. This was taken at different days after sowing (80 DAS and at harvest) separately.

3.5.1.4 Number of tillers plant^{-1}

At different DAS it was taken from five plants separately and then averaged.

3.5.1.5 Grain weight spike^{-1} (g)

At the time of harvest, from thirty plants it was measured by the following formula

$$\text{Grain weight spike}^{-1}\text{ (g)} = \frac{\text{Grain weight (g)}}{\text{Number of spike}}$$

3.5.1.6 Dry weight plant^{-1} (g)

Five plants at different days after sowing (30, 60, 90 DAS and at the time of harvest) were collected and dried at 70° C for 24 hours. The dried samples were then weighed and averaged.

3.5.1.7 Weight of 1000 seed (g)

One thousand cleaned dried seeds were counted randomly from each harvest sample and weighed by using a digital electric balance.

3.5.1.8 Grain yield (t ha^{-1})

Wheat was harvested randomly from pre-selected 1 m^2 in land from the centre of each plot. Then the harvested wheat was threshed, cleaned and sun dried up to 12% moisture level. The dried seeds were then weighed and averaged. The seed yield was converted into t ha^{-1}.

3.5.1.9 Plant population of wheat

Plant population m^{-2} was counted with an iron made square put in the middle of the plot.

3.5.1.10 Harvest Index (%)

Harvest Index was done plot wise as per experimental treatments by the following formula

$$\text{Harvest Index (HI)} = \frac{\text{Grain yield (t ha}^{-1}\text{)}}{\text{Straw yield (t ha}^{-1}\text{)} + \text{grain yield (t ha}^{-1}\text{)}} \times 100$$

3.5.2 Lentil

3.5.2.1 Plant height (cm)

The height of five plants was measured from the ground level to tip of the plants and then averaged. It was taken at 30, 60, 90 DAS and at harvest.

3.5.2.2 Number of branches plant^{-1}

Total number of branches from five plants were counted and then averaged. Number of branches was counted at 30, 60, 90 DAS and at harvest.

3.5.2.3 Number of pods plant^{-1}

Number of pods plant^{-1} was taken from five plants separately and then averaged.

3.5.2.4 Pod weight plant^{-1}

At different DAS it was taken from five plants separately and then averaged.

3.5.2.5 Weight of 1000 seeds (g)

One thousand cleaned dried seeds were counted randomly from each harvest sample and weighed by using a digital electric balance and the mean weight was expressed in gram.

3.5.2.6 Grain yield (t ha^{-1})

Wheat was harvested randomly from pre-selected 1 m^2 in land from the centre of each plot. Then the harvested lentil was threshed, cleaned and sun dried up to the moisture level of 12%. The dried seeds were then weighed and averaged. The seed yield was converted into t ha^{-1}.

3.5.2.7 Plant population of lentil

Plant population m^{-2} was counted with an iron made square put in the middle of the plot.

3.5.2.8 Harvest Index (%)

Harvest Index was taken plot wise as per experimental treatments by the following formula

$$\text{Harvest Index (HI\%)} = \frac{\text{Grain yield (t ha}^{-1}\text{)}}{\text{Straw yield (t ha}^{-1}\text{)} + \text{grain yield (t ha}^{-1}\text{)}} \times 100$$

3.6 Productivity performance

Total number of labourers used for the different operations were recorded with cost of variable inputs to compute the variable cost of different treatments. The cost and return analysis were done for each treatment on hectare basis. Here, productivity performance was discussed in terms of land equivalent ratio (LER), net income and benefit: cost ratio.

3.6.1 Land equivalent ratio (LER)

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

$$\text{LER} = \frac{\text{Yield of the intercropped wheat}}{\text{Yield of the sole wheat}} + \frac{\text{Intercrop yield of companion crop}}{\text{Yield of sole companion crop}}$$

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.

3.6.2 Net income

The net income (Tk. ha^{-1}) was calculated for each component crop separately as per following formula.

Net income = Total return (Tk. ha^{-1}) – Total cost of production (Tk. ha^{-1})

To calculate net income, rate of different input and output cost was given in the Appendix III.

3.6.3 Benefit- cost ratio (BCR)

In order to compare better performance, benefit : cost ratio (BCR) was calculated. BCR value was computed from the total cost of production and net return according to the following formula.

$$\text{Benefit- cost ratio (BCR)} = \frac{\text{Gross return (Tk. ha}^{-1}\text{)}}{\text{Total cost of production (Tk. ha}^{-1}\text{)}}$$

3.7 Statistical analysis

The data collected on different parameters were statistically analyzed using the MSTAT computer package programme developed by Russel (1986). Least Significant Difference (LSD) technique at 5% level of significance was used to compare the mean differences among the treatments (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

CHAPTER 4

Results and Discussion

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

4.1 Wheat

4.1.1 Plant height

Plant height of wheat was significantly affected by the intercropping with lentil under different seed rate ratio (Table 1). Plant height increased with the advancement of crop age. At 30 DAS, the tallest plant was 33.24 cm, while at maturity it was 97.63 cm. At all the stages, T_1 showed significantly the highest plant height. However, $T_3 - T_{12}$ for 30 and 45 DAS and $T_3 - T_{11}$ for 90 DAS and at the time of harvest respectively showed gradually decreased plant height. At 90 DAS and at the time of harvest the lowest plant height was shown by T_{11}. Similar findings were also found by Nargis *et al.* (2004). They reported that plant height of wheat was significantly affected by intercropping under wheat – lentil intercropping system. Highest plant height was shown in sole and also when intercropped at 80% wheat + 20% lentil seed rates.

Table 1. Plant height at different growth stages of wheat sole and as mixed cropped with lentil under different seed rates

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
T_1	33.24	71.22	94.56	97.63
T_3	32.22	70.85	89.89	94.21
T_4	31.16	66.61	89.11	91.54
T_5	30.57	65.66	88.22	90.40
T_6	30.34	63.66	87.89	89.82
T_7	30.29	63.11	87.00	86.13
T_8	29.09	62.22	86.00	85.49
T_9	29.05	62.83	83.33	84.92
T_{10}	28.87	60.89	82.55	83.80
T_{11}	28.03	59.45	82.39	81.53
T_{12}	26.37	56.94	83.72	84.73
$LSD_{0.05}$	2.013	3.049	2.798	1.269
CV (%)	6.95	7.80	5.89	6.84

Here,

T_1 = Sole wheat

$T_3 = W_{90}\ L_{10}$

$T_4 = W_{80}\ L_{20}$

$T_5 = W_{70}\ L_{30}$

$T_6 = W_{60}\ L_{40}$

$T_7 = W_{50}\ L_{50}$

$T_8 = W_{40}\ L_{60}$

$T_9 = W_{30}\ L_{70}$

$T_{10} = W_{20}\ L_{80}$

$T_{11} = W_{10}\ L_{90}$

$T_{12} = W_{100}\ L_{100}$

4.1.2 Number of tillers plant^{-1}

Number of tillers plant^{-1} of wheat was significantly affected by intercropping system at different days after sowing (Table 2). At 30 DAS, the highest number of tillers plant^{-1} was recorded to be 2.55 while at harvest it was 6.17 in T_1. At different DAS, T_1 showed the highest tiller numbers plant^{-1}. At 30 DAS, 60 DAS, 90 DAS and at the time of harvest, T_3 and T_5 showed the similar results but those were lesser than T_1. Treatment T_4 and Treatment $T_6 - T_{11}$ showed gradually decreased number of tillers plant^{-1} and T_{11} showed the lowest number of tillers plant^{-1} at all the stages in comparison with T_1 except T_{12} at 30 DAS. Different fertilizer doses and different seed rate combinations might be responsible for this type of variation. Dissimilar findings were reported by Nargis *et al.* (2004)) and Ashok *et al.* (2001) who found that number of tillers plant^{-1} of wheat was not significantly affected by wheat-based intercropping system. Singh, *et al.* (1996) also reported similar result. Islam (2006) also found that number of tillers plant^{-1} of wheat was not significantly affected by wheat-based intercropping system.

Table 2. Number of tillers plant[-1] at different growth stages of wheat sole and as mixed cropped with lentil under different seed rates

Treatments	Number of tillers plant^{-1}			
	30 DAS	60 DAS	90 DAS	At harvest
T_1	2.55	3.22	4.77	6.17
T_3	2.22	3.00	4.23	5.40
T_4	1.99	2.78	4.22	5.03
T_5	2.17	2.98	4.24	5.28
T_6	1.66	2.55	3.55	4.13
T_7	1.55	2.33	3.22	4.04
T_8	1.44	2.00	2.89	3.80
T_9	1.33	1.77	2.55	3.48
T_{10}	1.22	1.44	2.44	2.88
T_{11}	1.88	1.22	2.33	2.73
T_{12}	1.11	1.87	2.11	3.09
$LSD_{0.05}$	0.447	0.689	0.609	1.60
CV (%)	15.46	17.98	9.67	12.44

Here,

T_1 = Sole wheat

$T_3 = W_{90}\ L_{10}$

$T_4 = W_{80}\ L_{20}$

$T_5 = W_{70}\ L_{30}$

$T_6 = W_{60}\ L_{40}$

$T_7 = W_{50}\ L_{50}$

$T_8 = W_{40}\ L_{60}$

$T_9 = W_{30}\ L_{70}$

$T_{10} = W_{20}\ L_{80}$

$T_{11} = W_{10}\ L_{90}$

$T_{12} = W_{100}\ L_{100}$

4.1.3 Number of spikes plant^{-1}

Number of spikes plant^{-1} of wheat was significantly affected by the intercropping system at different days after sowing (Fig. 1). At 80 DAS, the highest number of spikes plant^{-1} was recorded to be 3.00 while at harvest it was 6.17 in T_1. At different DAS, T_1 showed the highest number of spikes plant^{-1}. At 90 DAS and at the time of harvest, T_3 and T_5 showed the similar results but those were lesser than T_1. Treatment T_4 and Treatment $T_6 - T_{11}$ showed gradually decreased number of spikes plant^{-1} and T_{11} showed the lowest number of spikes plant^{-1} at all the stages in comparison with T_1. Different fertilizer doses and different seed rate combinations might be responsible for this type of variation. Singh *et al.* (1996) reported that there was no significant effect of spike number of wheat with intercropping system. They also reported that number of spike depended on the effective tiller in most cases.

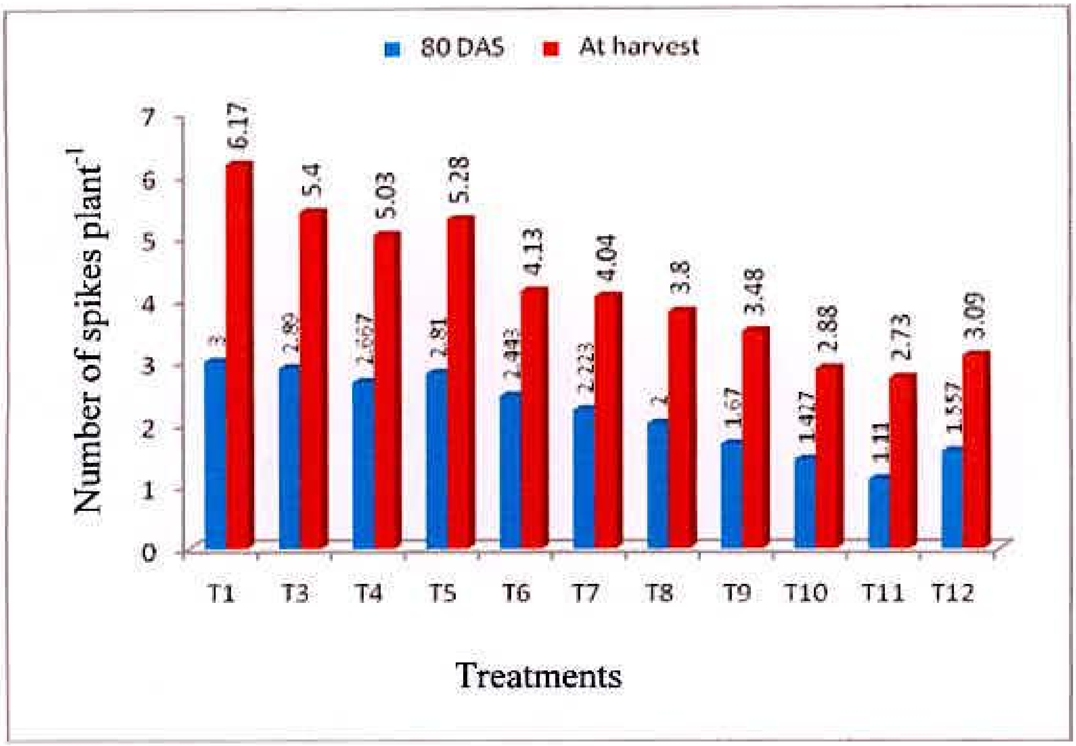

Fig. 1. Number of spikes plant^{-1} at different growth stages of wheat sole and as mixed cropped with lentil under different seed rates ($LSD_{0.05}$ = 1.60)

Here,

T_1 = Sole wheat	$T_8 = W_{40}\ L_{60}$
$T_3 = W_{90}\ L_{10}$	$T_9 = W_{30}\ L_{70}$
$T_4 = W_{80}\ L_{20}$	$T_{10} = W_{20}\ L_{80}$
$T_5 = W_{70}\ L_{30}$	$T_{11} = W_{10}\ L_{90}$
$T_6 = W_{60}\ L_{40}$	$T_{12} = W_{100}\ L_{100}$
$T_7 = W_{50}\ L_{50}$	

4.1.4 Spike length

Spike length of wheat was significantly affected by the intercropping systems (Fig. 2). Spike length increased with the advancement of age. At 80 DAS, the lowest spike length was 10.39 cm, while at maturity it was 12.74 cm. At all the stages, T_1 showed significantly the highest spike length. However, $T_3 - T_6$ and $T_3 - T_5$ showed spike length, which were significantly similar to T_1 at 80 DAS and at harvest, respectively. Treatment $T_7 - T_{11}$ and Treatment $T_6 - T_{11}$ showed gradually decreased spike length, respectively and T_{11} showed the shorest of spike length at all the stages. The treatment T_{12} showed spike lengths which were statistically similar with T_{11} at all growth stages. Ghanbari *et al.* (2002) and Nargis *et al.* (2004) reported significant effect on spike length of wheat by intercropping system. They reported that proper fertilization under intercropping system increased spike length of wheat.

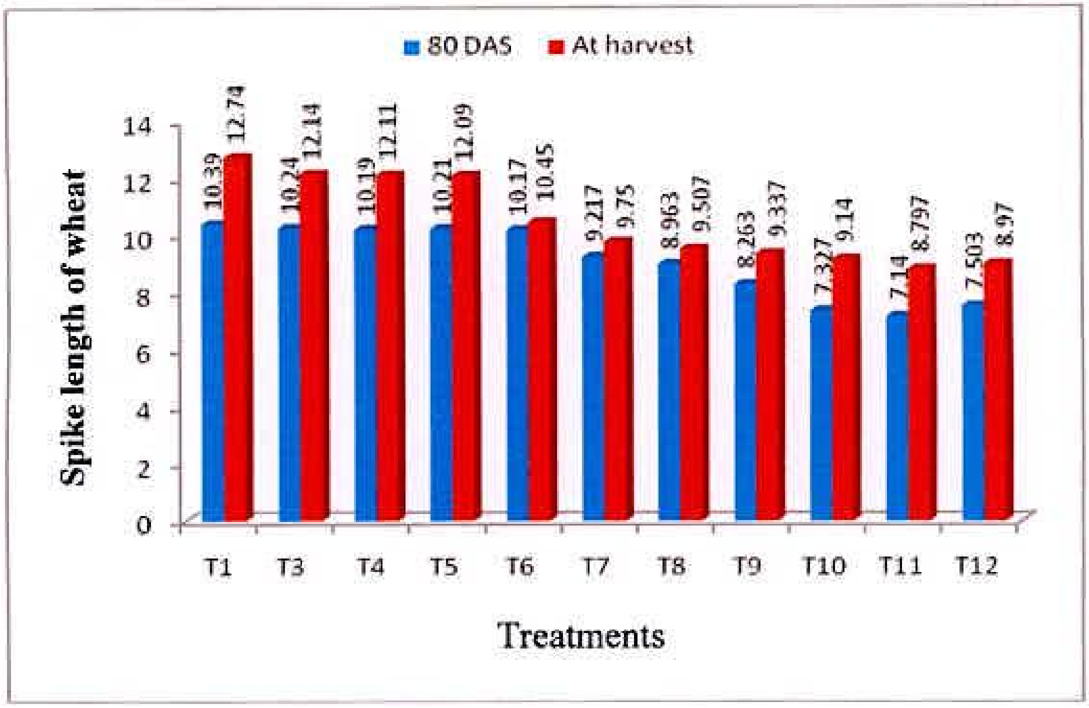

Fig. 2. Spike length of wheat sole and as mixed cropping with lentil at different seed rates ($LSD_{0.05} = 0.933$)

Here,

T_1 = Sole wheat	$T_8 = W_{40}\ L_{60}$
$T_3 = W_{90}\ L_{10}$	$T_9 = W_{30}\ L_{70}$
$T_4 = W_{80}\ L_{20}$	$T_{10} = W_{20}\ L_{80}$
$T_5 = W_{70}\ L_{30}$	$T_{11} = W_{10}\ L_{90}$
$T_6 = W_{60}\ L_{40}$	$T_{12} = W_{100}\ L_{100}$
$T_7 = W_{50}\ L_{50}$	

4.1.5 Dry matter weight plant^{-1}

Dry matter weight of wheat was significantly affected by the intercropping systems (Table 3). It increased with the advancement of age and at all the stages, T_1 showed the highest result. At 30 DAS, the highest dry weight plant^{-1} was 0.95 g which increased gradual at 60, 90 and at harvest having the values 5.53, 13.56 and 20.56 g, respectively. However, at 30, 60 and 90 DAS, T_3 - T_{12} showed gradually decreased dry weight plant^{-1} and at the time of harvest T_3 - T_{11} showed gradually decreased result. The lowest dry matter weight plant^{-1} at 30, 60 and 90 DAS was shown by T_{12} (0.56, 2.03 and 6.75 g, respectively) and at the time of harvest T_{11} showed the lowest dry matter weight plant^{-1} (10.92 g). T_1 showed better result because there was no competition with lentil. But $T_3 - T_5$ performed well because of having more wheat population and 100% recommended dose of fertilizers.

Table 3. Dry weight plant^{-1} at different growth stages of wheat mixed cropped with lentil under different seed rates

Treatments	Dry weight plant^{-1}(g)			
	30 DAS	60 DAS	90 DAS	At harvest
T_1	0.95	5.53	13.56	20.56
T_3	0.94	4.87	12.56	18.59
T_4	0.86	4.48	11.69	17.75
T_5	0.86	4.38	12.51	17.68
T_6	0.85	3.81	10.00	16.14
T_7	0.73	3.54	9.47	16.00
T_8	0.71	3.23	8.92	14.93
T_9	0.63	2.99	7.63	14.05
T_{10}	0.68	2.83	7.04	12.63
T_{11}	0.70	2.64	6.92	10.92
T_{12}	0.56	2.03	6.75	11.88
$LSD_{0.05}$	0.170	0.516	1.222	2.213
CV (%)	13.03	8.13	7.35	8.35

Here,

T_1 = Sole wheat
$T_3 = W_{90}\ L_{10}$
$T_4 = W_{80}\ L_{20}$
$T_5 = W_{70}\ L_{30}$
$T_6 = W_{60}\ L_{40}$
$T_7 = W_{50}\ L_{50}$
$T_8 = W_{40}\ L_{60}$
$T_9 = W_{30}\ L_{70}$
$T_{10} = W_{20}\ L_{80}$
$T_{11} = W_{10}\ L_{90}$
$T_{12} = W_{100}\ L_{100}$

4.1.6 Number of seeds spike^{-1}

Number of seeds spike^{-1} was significantly affected by intercropping system (Table 4). At the time of harvest, the highest number of seeds spike^{-1} was recorded (15.12) in T_1. The highest number of seeds spike^{-1} in sole wheat might be attributed to the lack of competition with lentil. Treatment $T_3 - T_5$ gave the were results which statistically similar with T_1. Treatment $T_6 - T_{12}$ showed gradually decreased number of seeds spike^{-1} and among them T_{12} gave the lowest number of seeds spike^{-1} (7.92). Ashok *et al.* (2001) reported grain weight spike^{-1} of wheat intercropped with cowpea which was not significantly lower from sole crop.

Table 4. Number of seeds spike^{-1} at harvest at different growth stages of wheat sole and as mixed cropped with lentil under different seed rates

Treatments	Number of seeds spike^{-1} at harvest
T_1	15.12
T_3	14.85
T_4	14.73
T_5	14.61
T_6	12.42
T_7	10.80
T_8	10.86
T_9	9.28
T_{10}	9.12
T_{11}	8.24
T_{12}	7.920
$LSD_{0.05}$	1.276
CV (%)	6.59

Here,

T_1 = Sole wheat

$T_3 = W_{90} L_{10}$

$T_4 = W_{80} L_{20}$

$T_5 = W_{70} L_{30}$

$T_6 = W_{60} L_{40}$

$T_7 = W_{50} L_{50}$

$T_8 = W_{40} L_{60}$

$T_9 = W_{30} L_{70}$

$T_{10} = W_{20} L_{80}$

$T_{11} = W_{10} L_{90}$

$T_{12} = W_{100} L_{100}$

4.1.7 Thousand seed weight

Thousand seed weight of wheat was significantly affected by intercropping system (Table 5). T_1 sole wheat produced the maximum1000 seeds weight (43.73 g). $T_3 - T_5$ gave 1000-seed weights which were statistically similar to T_1. $T_6 - T_{11}$ showed gradual decreased values and T_{11} gave the lowest 1000 seed weight (37.40 g) which was statistically similar to T_{10}. Treatment T_{12} gave the result (39.67 g) which was statistically similar to T_9 (40.50 g). The variation in 1000-seed weight among the treatments might be attributed to the competition for resources with the lentil under intercropping system. Nargis *et al.* (2004) reported that 1000-seed weight did not significantly vary with intercropping. Likewise, Cheng *et al.* (2003) reported that higher nitrogen application under wheat + blackgram intercropping system, 1000-seed weight was greater than monocropped wheat.

Table 5. Weight of 1000-seeds (g) of wheat sole and as mixed cropped with lentil under different seed rates

Treatments	1000 seed wt (g)
T_1	43.73
T_3	42.90
T_4	42.63
T_5	42.87
T_6	41.47
T_7	41.37
T_8	41.10
T_9	40.50
T_{10}	38.47
T_{11}	37.40
T_{12}	39.67
$LSD_{0.05}$	2.024
CV (%)	7.90

Here,

T_1 = Sole wheat

$T_3 = W_{90}\ L_{10}$

$T_4 = W_{80}\ L_{20}$

$T_5 = W_{70}\ L_{30}$

$T_6 = W_{60}\ L_{40}$

$T_7 = W_{50}\ L_{50}$

$T_8 = W_{40}\ L_{60}$

$T_9 = W_{30}\ L_{70}$

$T_{10} = W_{20}\ L_{80}$

$T_{11} = W_{10}\ L_{90}$

$T_{12} = W_{100}\ L_{100}$

4.1.8 Total grain yield

Grain yield was significantly affected by intercropping system (Table 6). T_1 gave the maximum yield (3.14 t ha^{-1}) and $T_3 - T_4$ gave results (2.92, 2.88 and 2.84 t ha^{-1} ,respectively) which were not significantly different from that of T_1. $T_6 - T_{11}$ gave gradually decreased yields and T_{11} gave the lowest yield (0.61 t ha^{-1}). However, T_{12} showed yields (0.97 t ha^{-1}) which was statistically similar to T_9 (0.93 t ha^{-1}). Similar result was also reported by Singh *et al.* (1996). They reported that the yield of wheat or lentil individually under wheat + lentil intercropping system was significantly higher but lower from combined yield. The application of increased N increased grain yield of wheat which was not significantly higher than that obtained under recommended dose.

Table 6. Total grain yield (t ha^{-1}) of wheat sole and as mixed cropped with lentil under different seed rates

Treatments	Yield (t ha^{-1})
T_1	3.14
T_3	2.92
T_4	2.88
T_5	2.84
T_6	1.96
T_7	1.39
T_8	1.29
T_9	0.93
T_{10}	0.94
T_{11}	0.61
T_{12}	0.97
$LSD_{0.05}$	0.696
CV (%)	12.61

Here,

T_1 = Sole wheat

$T_3 = W_{90}\ L_{10}$

$T_4 = W_{80}\ L_{20}$

$T_5 = W_{70}\ L_{30}$

$T_6 = W_{60}\ L_{40}$

$T_7 = W_{50}\ L_{50}$

$T_8 = W_{40}\ L_{60}$

$T_9 = W_{30}\ L_{70}$

$T_{10} = W_{20}\ L_{80}$

$T_{11} = W_{10}\ L_{90}$

$T_{12} = W_{100}\ L_{100}$

4.1.9 Harvest Index (%)

Harvest index (%) was significantly affected by intercropping system (Fig. 3). Among the treatments, T_5 gave the highest harvest index (44.48%) which statistically similar to T_1 (44.41%), T_3 (43.26%) and T_4 (41.32%), respectively. T_{12} gave the lowest harvest index (29.68%). Treatments $T_6 - T_{11}$ were at par in respect of harvest index values which were significantly lower from that of T_1, T_3 and T_5. Islam (2006) found that harvest index of wheat was significantly affected by intercropping systems.

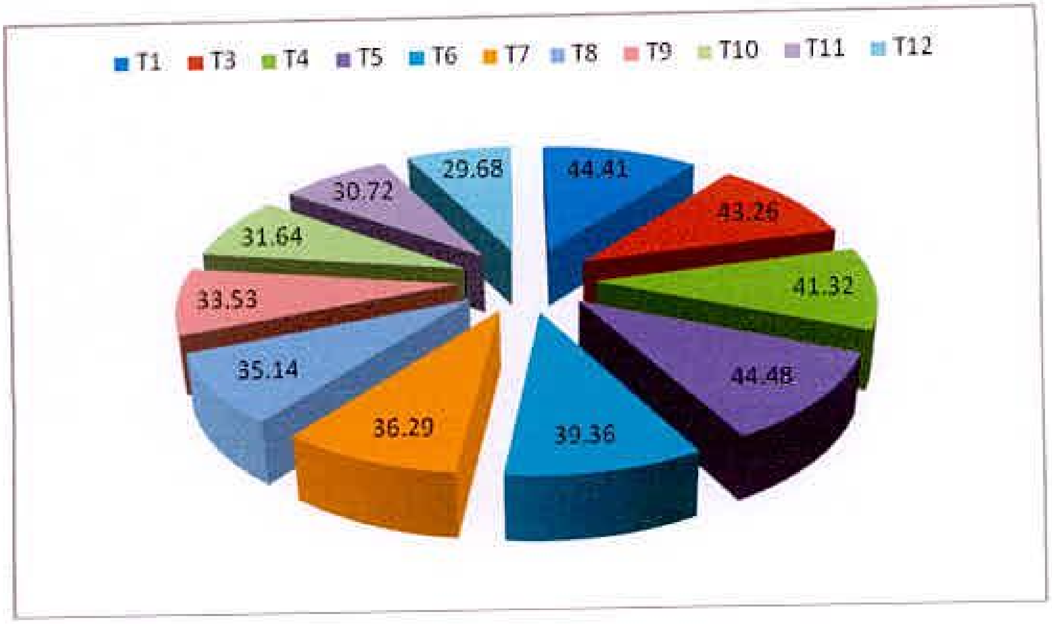

Fig. 3. Harvest Index% of wheat sole and as mixed cropped with lentil under different seed rates ($LSD_{0.05} = 4.931$)

Here,

T_1 = Sole wheat

$T_3 = W_{90}\ L_{10}$

$T_4 = W_{80}\ L_{20}$

$T_5 = W_{70}\ L_{30}$

$T_6 = W_{60}\ L_{40}$

$T_7 = W_{50}\ L_{50}$

$T_8 = W_{40}\ L_{60}$

$T_9 = W_{30}\ L_{70}$

$T_{10} = W_{20}\ L_{80}$

$T_{11} = W_{10}\ L_{90}$

$T_{12} = W_{100}\ L_{100}$

4.1.10 Plant population of wheat

Plant population m^{-2} of wheat was significantly affected with different seed rates of intercropping patterns (Table 7). The highest population m^{-2} of wheat (108.4) was obtained from the treatment T_1 and the lowest (18.33) from the treatment T_{11}. T_3 – T_{11} showed gradual decreased population density because of gradual decreased seed rates of wheat. According to the change in seed rate, plant population m^{-2} was also changed and T_3 – T_6 and T_{12} showed comparatively higher plant population m^{-2} than the later ones and T_7 – T_{10} showed comparatively lower plant population m^{-2}.

Table 7. Plant population m^{-2} of wheat sole and as mixed cropped with lentil under different seed rates

Treatments	Plant m^{-2} (wheat)
T_1	108.4
T_2	--
T_3	98.68
T_4	88.33
T_5	80.68
T_6	72.33
T_7	58.33
T_8	48.68
T_9	36.68
T_{10}	24.33
T_{11}	18.33
T_{12}	78.68
$LSD_{0.05}$	2.833
CV (%)	8.56

Here,

T_1 = Sole wheat
T_2 = Sole lentil
$T_3 = W_{90}\ L_{10}$
$T_4 = W_{80}\ L_{20}$
$T_5 = W_{70}\ L_{30}$
$T_6 = W_{60}\ L_{40}$
$T_7 = W_{50}\ L_{50}$
$T_8 = W_{40}\ L_{60}$
$T_9 = W_{30}\ L_{70}$
$T_{10} = W_{20}\ L_{80}$
$T_{11} = W_{10}\ L_{90}$
$T_{12} = W_{100}\ L_{100}$

4.2 Lentil

4.2.1 Plant height

Plant height of lentil was significantly affected by the intercropping systems (Table 8). Plant height increased with the advancement of crop age. At 30 DAS, treatment T_{10} showed the tallest plant (13.60 cm) and T_3 showed the shortest plant height (10.57 cm). Treatment T_2, $T_4 - T_{9,}$ T_{11} and T_{12} gave the similar plant height to T_{10} at 30 DAS. It was observed that at 60, 90 DAS and at harvest, treatment T_3 gave the tollest plant height (30.78, 44.28 and 52.24 cm respectively) and treatment $T_4 - T_{11}$ showed gradual decreased in plant height and T_2 showed the shortest plant (20.44, 30.00 and 38.77 cm respectively) at 60, 90 DAS and at harvest.

Table: 8. Plant height of lentil sole and as mixed cropped with wheat under different seed rates at different growth stages

Treatments	Plant height of lentil (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
T_2	13.24	20.44	30.00	38.77
T_3	10.57	30.78	44.28	52.24
T_4	11.09	28.27	43.06	52.02
T_5	11.14	26.66	41.59	51.23
T_6	11.66	26.44	38.98	50.47
T_7	11.90	26.33	37.36	49.62
T_8	12.58	26.22	36.00	46.72
T_9	13.11	26.00	33.89	46.32
T_{10}	13.60	26.05	33.05	43.65
T_{11}	13.47	25.50	31.66	37.66
T_{12}	11.90	23.28	37.53	41.38
$LSD_{0.05}$	2.545	3.122	4.004	1.625
CV (%)	10.46	7.05	6.35	7.06

Here,

T_2 = Sole lentil
$T_3 = W_{90}\ L_{10}$
$T_4 = W_{80}\ L_{20}$
$T_5 = W_{70}\ L_{30}$
$T_6 = W_{60}\ L_{40}$
$T_7 = W_{50}\ L_{50}$
$T_8 = W_{40}\ L_{60}$
$T_9 = W_{30}\ L_{70}$
$T_{10} = W_{20}\ L_{80}$
$T_{11} = W_{10}\ L_{90}$
$T_{12} = W_{100}\ L_{100}$

4.2.2 Number of branches plant^{-1}

Number of branches plant^{-1} of lentil was significantly affected by the intercropping systems (Table 9). Number of branches increased with the advancement of crop age. At 30 DAS, the highest number of branches plant^{-1} (1.56) was found in T_2, while at maturity it was 4.98. Across all the stages, T_2 showed significantly the highest number of branches plant^{-1} (1.56, 3.11, 4.78 and 4.98, respectively). However, treatment, T_3 showed the lowest number of branches plant^{-1} (1.44, 1.11, 1.33 and 1.68, respectively) and treatment $T_4 - T_{11}$ showed gradual increased in number of branches plant^{-1} at 60, 90 DAS and at harvest. It might be caused by plant population and competitiveness of lentil with wheat. In T_2, there was no shading effect of wheat plant as it was a sole lentil which promoted to produce highest number of branches plant^{-1}. Nargis *et al.* (1996) also reported same result while conducting an experiment on wheat + lentil intercropping system.

Table 9. Number of branches plant^{-1} of lentil sole and as mixed cropped with wheat under different seed rates

Treatments	Number of branches plant^{-1}			
	30 DAS	60 DAS	90 DAS	At harvest
T_2	1.56	3.11	4.78	4.98
T_3	1.44	1.11	1.33	1.68
T_4	0.77	1.22	1.56	2.09
T_5	0.88	1.44	1.78	2.65
T_6	0.89	1.67	2.11	2.32
T_7	1.09	1.78	2.22	3.10
T_8	1.11	1.89	2.44	3.15
T_9	1.11	2.22	2.56	3.48
T_{10}	1.22	2.22	2.89	4.11
T_{11}	0.66	2.66	3.33	4.33
T_{12}	0.88	1.68	2.00	3.33
$LSD_{0.05}$	0.756	0.4907	0.7226	0.318
CV (%)	11.93	15.06	17.30	5.83

Here,

T_2 = Sole lentil

$T_3 = W_{90}\ L_{10}$

$T_4 = W_{80}\ L_{20}$

$T_5 = W_{70}\ L_{30}$

$T_6 = W_{60}\ L_{40}$

$T_7 = W_{50}\ L_{50}$

$T_8 = W_{40}\ L_{60}$

$T_9 = W_{30}\ L_{70}$

$T_{10} = W_{20}\ L_{80}$

$T_{11} = W_{10}\ L_{90}$

$T_{12} = W_{100}\ L_{100}$

4.2.3 Dry weight plant^{-1}

Dry matter weight of lentil was significantly affected by the intercropping systems (Table 10). At all stages it was observed that the highest values of dry weight plant^{-1} (0.53, 1.88, 3.86 and 3.74 g at 30, 60, 90 DAS and at harvest, respectively) were found in the treatment T_2. Again at all stages T_3 showed the lowest value of dry matter plant^{-1}. At 30, 90 DAS and at harvest T_{11}, $T_{10} - T_{11}$ and $T_8 - T_{11}$ showed the values which were statistically similar to T_2. At the time of harvest $T_4 - T_7$ and T_{12} showed the values which were statistically similar toT_3. At all stages it was observed that treatment $T_3 - T_{11}$ showed gradual increased in dry matter weight plant^{-1}. The highest dry matter of T_2 may be attributed to better growth rhythm, more availability of light, nutrient supply and water requirements for sole lentil as there was no competition (Singh, 1979; Singh, 1983).

Table 10. Dry weight plant^{-1} of lentil sole and as lentil mixed cropped with wheat under different seed rates

Treatments	Dry weight plant^{-1} (g)			
	30 DAS	60 DAS	90 DAS	At harvest
T_2	0.53	1.88	3.86	3.74
T_3	0.18	0.47	1.46	2.43
T_4	0.24	0.59	1.58	2.55
T_5	0.26	0.66	1.66	2.64
T_6	0.28	0.69	1.70	2.66
T_7	0.33	0.75	1.75	2.73
T_8	0.35	1.00	2.00	2.99
T_9	0.38	1.03	2.04	3.04
T_{10}	0.41	1.19	2.20	3.12
T_{11}	0.45	1.12	2.13	3.20
T_{12}	0.23	0.56	1.56	2.54
$LSD_{0.05}$	0.076	0.414	1.664	1.601
CV (%)	13.24	16.94	12.61	16.77

Here,

T_2 = Sole lentil
$T_3 = W_{90}\ L_{10}$
$T_4 = W_{80}\ L_{20}$
$T_5 = W_{70}\ L_{30}$
$T_6 = W_{60}\ L_{40}$
$T_7 = W_{50}\ L_{50}$
$T_8 = W_{40}\ L_{60}$
$T_9 = W_{30}\ L_{70}$
$T_{10} = W_{20}\ L_{80}$
$T_{11} = W_{10}\ L_{90}$
$T_{12} = W_{100}\ L_{100}$

4.2.4 Number of Flowers plant^{-1}

Number of flowers plant^{-1} of lentil was significantly affected by the intercropping systems (Table 11). At 60 DAS (during flowering stage), it was observed that the highest value of number of flowers plant^{-1} (8.22) was reported in the treatment T_2 and followed by T_{11} (7.67) which was significantly similar to that of T_2. It was observed that treatment $T_3 - T_{11}$ showed gradual increased in the number of flowers plant^{-1} and T_3 showed the lowest number of flowers plant^{-1} (2.55). The highest number of flowers plant^{-1} of T_2 may be attributed to better growth rhythm, more supply of light, nutrient and water for sole lentil as there was no competition (Singh, 1979; Singh, 1983).

Table 11. Number of flowers $plant^{-1}$ of lentil sole and as mixed cropped with wheat under different seed rates

Treatments	Number of Flowers $plant^{-1}$
	60 DAS
T_2	8.22
T_3	2.55
T_4	2.89
T_5	3.43
T_6	3.55
T_7	3.89
T_8	4.55
T_9	5.34
T_{10}	6.11
T_{11}	7.67
T_{12}	3.99
$LSD_{0.05}$	1.018
CV (%)	12.59

Here,

T_2 = Sole lentil

$T_3 = W_{90}\ L_{10}$

$T_4 = W_{80}\ L_{20}$

$T_5 = W_{70}\ L_{30}$

$T_6 = W_{60}\ L_{40}$

$T_7 = W_{50}\ L_{50}$

$T_8 = W_{40}\ L_{60}$

$T_9 = W_{30}\ L_{70}$

$T_{10} = W_{20}\ L_{80}$

$T_{11} = W_{10}\ L_{90}$

$T_{12} = W_{100}\ L_{100}$

4.2.5 Number of pods plant^{-1}

Number of pods plant^{-1} of lentil was significantly affected by the intercropping systems (Table 12). At 70 DAS (during pod formation stage) and at harvest, it was observed that the highest values of number of pods plant^{-1} (26.44 and 39.77, respectively) was found in the treatment T_2. Treatment T_{11} showed the higher value (20.78 and 30.77) at 70 DAS and at harvest respectively but it was significantly different from that of T_2. It was also observed that treatment T_3 – T_{11} showed gradual increased in the number of pods plant^{-1} and T_3 showed the lowest value (7.22 and 10.67) in both cases. At 70 DAS, T_4 – T_6 showed similar result as was found with T_3. At the time of harvest treatment T_{12} showed the value (30.55) which was statistically similar tothat of T_{11} (30.77). Howlader (2006) reported that number of pods plant^{-1} of bushbean was significantly affected by intercropping patterns. He showed that the highest number of pods plant^{-1} was found where there was no or less competition for space light, water and nutrients.

Table 12. Number of pods $plant^{-1}$ of lentil sole and as mixed cropped with wheat under different fertilizer doses and seed rates

Treatments	Number of pods $plant^{-1}$	
	70 DAS	At harvest
T_2	26.44	39.77
T_3	7.22	10.67
T_4	8.11	11.06
T_5	8.78	15.24
T_6	9.99	17.02
T_7	12.55	22.03
T_8	15.56	23.25
T_9	16.78	26.51
T_{10}	19.55	27.38
T_{11}	20.78	30.77
T_{12}	13.66	30.55
$LSD_{0.05}$	4.312	1.009
CV (%)	17.47	12.55

Here,

T_2 = Sole lentil

$T_3 = W_{90}\ L_{10}$

$T_4 = W_{80}\ L_{20}$

$T_5 = W_{70}\ L_{30}$

$T_6 = W_{60}\ L_{40}$

$T_7 = W_{50}\ L_{50}$

$T_8 = W_{40}\ L_{60}$

$T_9 = W_{30}\ L_{70}$

$T_{10} = W_{20}\ L_{80}$

$T_{11} = W_{10}\ L_{90}$

$T_{12} = W_{100}\ L_{100}$

4.2.6 Pod weight plant^{-1}

Pod weight plant^{-1} was significantly affected by intercropping system (Table 13). At the time of harvest, the highest pod weight plant^{-1} was recorded (1.75 g) in T_2. The highest pod weight plant^{-1} in sole lentil might be attributed to the lack of competition with wheat. T_{11} also gave the higher value (1.55 g) which was significantly different from that of T_2. $T_3 - T_{11}$ showed gradual increased result and the lowest pod weight plant^{-1} was (0.47 g) in the treatment T_3 which was not significantly different from T_4 (0.52 g). T_{12} gave the result (0.95 g) which was not significantly different from T_9 (0.97 g) and T_{10} (0.98 g). Such results might be due to differential nutrient uptake where different plant population resulted in nutrient competition.

Table 13. Pod weight plant^{-1} of lentil sole and as mixed cropped with wheat under different seed rates

Treatments	Pod weight plant^{-1} (g)
	At harvest
T_2	1.75
T_3	0.47
T_4	0.52
T_5	0.62
T_6	0.71
T_7	0.74
T_8	0.86
T_9	0.97
T_{10}	0.98
T_{11}	1.55
T_{12}	0.95
$LSD_{0.05}$	0.076
CV (%)	4.48

Here,

T_2 = Sole lentil

$T_3 = W_{90}\ L_{10}$

$T_4 = W_{80}\ L_{20}$

$T_5 = W_{70}\ L_{30}$

$T_6 = W_{60}\ L_{40}$

$T_7 = W_{50}\ L_{50}$

$T_8 = W_{40}\ L_{60}$

$T_9 = W_{30}\ L_{70}$

$T_{10} = W_{20}\ L_{80}$

$T_{11} = W_{10}\ L_{90}$

$T_{12} = W_{100}\ L_{100}$

4.2.7 Weight of 1000- seeds

Thousand seed weight of lentil was significantly affected by intercropping system (Table 14). T_2 produced the highest 1000-seed weight (23.20 g). T_{11} also gave higher 1000-seed weight (22.41 g) but this was significantly different from that of T_2. $T_3 - T_{11}$ gave 1000-seed weights which increased gradually and among them T_3 gave the lowest 1000 seed weight (19.20 g) but this was not significantly different from that of T_4. Treatment T_{12} gave the result (20.82 g) which was not significantly different from T_7 (20.80 g). The variation in 1000 seed weight among the treatments might be attributed to the competition for resources with the wheat under intercropping system. Nargis *et al.* (2004) reported that 1000-seed weight did not significantly different under intercropping system. But Cheng *et al.* (2003) reported that under higher nitrogen application under wheat + blackgram intercropping system, 1000-seed weight was greater than monocropped wheat or blackgram.

Table 14. Weight of 1000-seeds of lentil sole and as mixed cropped with wheat under different seed rates

Treatments	1000 Seed Wt (g)
	At harvest
T_2	23.20
T_3	19.20
T_4	19.22
T_5	19.80
T_6	20.40
T_7	20.80
T_8	22.00
T_9	22.21
T_{10}	22.22
T_{11}	22.41
T_{12}	20.82
$LSD_{0.05}$	0.132
CV (%)	7.36

Here,

T_2 = Sole lentil

$T_3 = W_{90}\ L_{10}$

$T_4 = W_{80}\ L_{20}$

$T_5 = W_{70}\ L_{30}$

$T_6 = W_{60}\ L_{40}$

$T_7 = W_{50}\ L_{50}$

$T_8 = W_{40}\ L_{60}$

$T_9 = W_{30}\ L_{70}$

$T_{10} = W_{20}\ L_{80}$

$T_{11} = W_{10}\ L_{90}$

$T_{12} = W_{100}\ L_{100}$

4.2.8 Total Grain yield

Grain yield was significantly affected by intercropping system (Table 15). T_2 gave the best result (1.04 t ha^{-1}). T_{11} also gave higher grain yield (0.91 t ha^{-1}) but it was significantly different from that of T_2. T_3 – T_{11} gave the result which increased gradually and among them T_3 gave the lowest grain yield (0.09 t ha^{-1}) but this was not significantly different from that of T_4 (0.16 g). Treatment T_{12} gave the result (0.37 t ha^{-1}) which was not significantly different from that of T_6 (0.327 t ha^{-1}). The variation in seed yield among the treatments might be attributed to the competition for resources with wheat under intercropping system.

Table 15. Total yield of lentil sole and as mixed cropped with wheat under different seed rates

Treatments	Yield (t ha^{-1})
T_2	1.04
T_3	0.09
T_4	0.16
T_5	0.37
T_6	0.39
T_7	0.43
T_8	0.52
T_9	0.66
T_{10}	0.76
T_{11}	0.91
T_{12}	0.37
$LSD_{0.05}$	0.076
CV (%)	7.49

Here,

T_2 = Sole lentil

$T_3 = W_{90}\ L_{10}$

$T_4 = W_{80}\ L_{20}$

$T_5 = W_{70}\ L_{30}$

$T_6 = W_{60}\ L_{40}$

$T_7 = W_{50}\ L_{50}$

$T_8 = W_{40}\ L_{60}$

$T_9 = W_{30}\ L_{70}$

$T_{10} = W_{20}\ L_{80}$

$T_{11} = W_{10}\ L_{90}$

$T_{12} = W_{100}\ L_{100}$

4.2.9 Harvest Index (%)

Harvest index was significantly affected by intercropping system (Fig. 4). Among the treatments, T_2 gave the highest harvest index (38.89%) which was not significantly similar to T_{11} (38.41%), T_9 (35.53%) and T_{10} (35.64%), respectively. T_3 gave the lowest harvest index (27.33) which was similar with T_4 (28.38%), T_5 (31.25%) and T_{12} (29.68%), respectively. Lower values of $T_6 - T_8$ were at par showing harvest index values which were significantly different from that of T_2 and T_{11}.

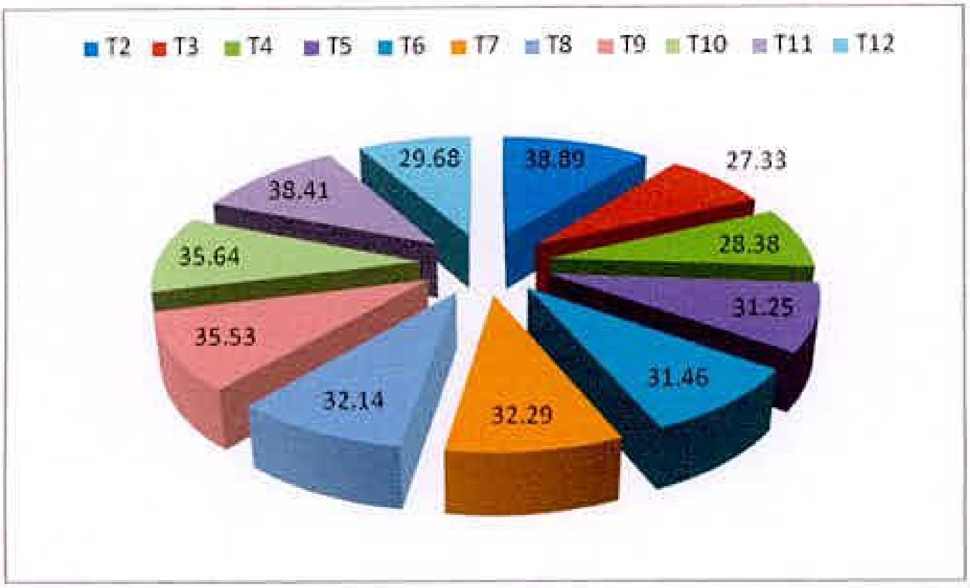

Fig. 4. Harvest Index of lentil sole and as mixed cropped with wheat under different seed rates ($LSD_{0.05}$ = 3.808)

Here,

T_2 = Sole lentil	$T_8 = W_{40}\ L_{60}$
$T_3 = W_{90}\ L_{10}$	$T_9 = W_{30}\ L_{70}$
$T_4 = W_{80}\ L_{20}$	$T_{10} = W_{20}\ L_{80}$
$T_5 = W_{70}\ L_{30}$	$T_{11} = W_{10}\ L_{90}$
$T_6 = W_{60}\ L_{40}$	$T_{12} = W_{100}\ L_{100}$
$T_7 = W_{50}\ L_{50}$	

4.2.10 Plant population of lentil

Population m^{-2} of lentil was significantly affected under different seed rates of intercropping systems (Table 16). The highest population m^{-2} of lentil (84.32) was obtained from the treatment T_2 which was not significantly higher than T_{11}. The lowest population m^{-2} (10.16) was recorded from the treatment T_3. $T_3 - T_{11}$ showed gradual increased of plant population, which was obvious superscript increased seed rates of lentil. According to seed rate plant population m^{-2} was displayed and $T_8 - T_{10}$ and T_{12} showed comparatively higher plant population m^{-2} and $T_3 - T_7$ showed comparatively lower plant population m^{-2}.

Table 16. Plant m^{-2} of lentil mixed cropped with wheat under different seed rates

Treatments	Plant m^{-2}
T_1	--
T_2	84.32
T_3	10.16
T_4	18.28
T_5	24.56
T_6	30.68
T_7	38.35
T_8	46.79
T_9	54.45
T_{10}	62.57
T_{11}	74.15
T_{12}	48.68
$LSD_{0.05}$	4.894
CV (%)	7.04

Here,

T_1 = Sole wheat
T_2 = Sole lentil
$T_3 = W_{90} L_{10}$
$T_4 = W_{80} L_{20}$
$T_5 = W_{70} L_{30}$
$T_6 = W_{60} L_{40}$
$T_7 = W_{50} L_{50}$
$T_8 = W_{40} L_{60}$
$T_9 = W_{30} L_{70}$
$T_{10} = W_{20} L_{80}$
$T_{11} = W_{10} L_{90}$
$T_{12} = W_{100} L_{100}$

4.3 Productivity Performance

4.3.1 Combined yield

The combined yield of wheat and lentil was significantly influenced by different intercropping systems (Fig. 5). The highest combined yield (3.21 t ha^{-1}) was found in $T_{5.}$ Treatment, T_3 and T_4 showed higher combined yield of 3.01 and 3.04 t ha^{-1}, respectively but these were significantly different from $T_{5.}$ Treatments $T_6 - T_{12}$ showed lower combined yields which were significantly lower than that of T_5. The lowest combined yield (1.34 t ha^{-1}) was obtained from $T_{12.}$ Similar result was also obtained by Singh *et al.* (1996). They reported that the combined yield of wheat and lentil under wheat-lentil intercropping system was significantly higher than that of the sole crop.

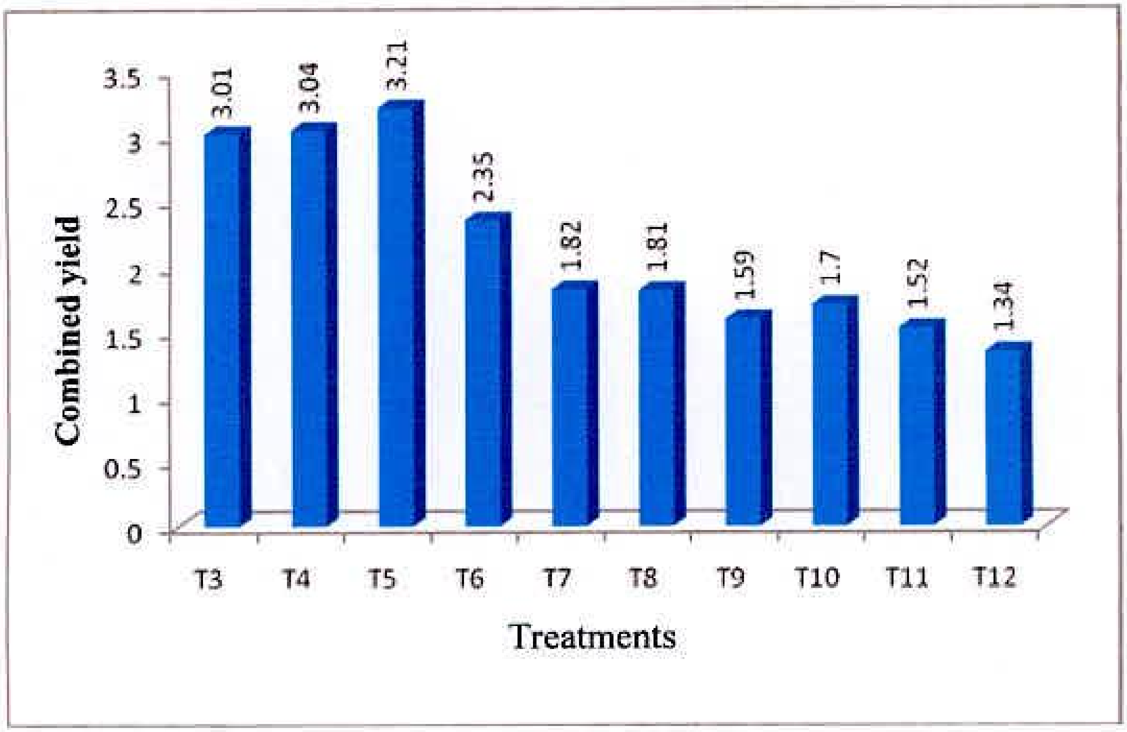

Fig. 5. Combined yields of wheat and lentil in mixed cropping system under different seed rates ($LSD_{0.05} = 0.133$)

Here,

$T_3 = W_{90}\ L_{10}$	$T_8 = W_{40}\ L_{60}$
$T_4 = W_{80}\ L_{20}$	$T_9 = W_{30}\ L_{70}$
$T_5 = W_{70}\ L_{30}$	$T_{10} = W_{20}\ L_{80}$
$T_6 = W_{60}\ L_{40}$	$T_{11} = W_{10}\ L_{90}$
$T_7 = W_{50}\ L_{50}$	$T_{12} = W_{100}\ L_{100}$

4.3.2 Land equivalent ratio (LER)

Land equivalent ratio (LER) of wheat and lentil was significantly influenced by different intercropping systems (Table 17). The highest LER (1.30) was found in T_5 and T_4 also gave similar result (1.11). Treatments T_3, T_6, T_8 – T_{10} and T_{12} showed lower LER values which were statistically similar but these values were significantly different from others. The lowest LER (0.68) was obtained from T_{11} which was statistically similar to T_7 (0.86).

Table 17. Land equivalent ratio (LER) of wheat- lentil mixed cropping under different seed rates

Treatments	Land equivalent ratio (LER)
T_1	--
T_2	--
T_3	1.06
T_4	1.11
T_5	1.30
T_6	1.03
T_7	0.86
T_8	0.93
T_9	0.94
T_{10}	1.04
T_{11}	0.68
T_{12}	1.08
$LSD_{0.05}$	0.203
CV (%)	11.81

Here,

$T_3 = W_{90} L_{10}$ $T_8 = W_{40} L_{60}$

$T_4 = W_{80} L_{20}$ $T_9 = W_{30} L_{70}$

$T_5 = W_{70} L_{30}$ $T_{10} = W_{20} L_{80}$

$T_6 = W_{60} L_{40}$ $T_{11} = W_{10} L_{90}$

$T_7 = W_{50} L_{50}$ $T_{12} = W_{100} L_{100}$

4.4.3 Net income

Net income provides an appropriate economic assessment of intercropping in terms of increased value per unit land. The highest net income (Tk. 61026.75 ha^{-1}) was obtained in T_5 (Table 18). The second highest net income (Tk. 45282.25 ha^{-1}) was found in T_4. Treatments $T_1 - T_3$ and T_{11} gave comparatively higher results but these were significantly different from that of T_5. The treatment T_{12} showed the lowest net income (Tk. 1833.50 ha^{-1}) and treatments $T_6 - T_{10}$ were also found to have less monetary advantage. Similar result was also found by Singh *et al.* (1996) who stated that the monetary advantage evaluated over the sole wheat indicated a positive gain from intercropping system. They tested wheat + lentil intercropping and found that maximum monetary advantage was recorded from wheat + lentil in 3:1 row ratio followed by 1:1 row ratio. Wheat when grown with lentil gave 24 to 46% higher monetary advantages over the sole wheat.

4.4.4 Benefit- cost ratio (BCR)

It is necessary to mention that higher benefit-cost ratio (BCR) indicated better result. In this study the value of benefit-cost ratio was significantly influenced by intercropping system (Table 18). It was observed that T_5 showed the best result (2.14) among the treatments. T_2 and T_4 also gave better result (1.99 and 1.84) but these were not significantly different from T_5. T_1, T_3 and $T_6 - T_{11}$ showed the results which were not so satisfactory compared to T_5 but were statistically similar to T_2 and T_4. T_{12} showed the lowest value (1.03).

Similar result was found by Malik *et al.* (1998) who stated that 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.

Table 18. Total cost of production, total income, net return and BCR in wheat- lentil mixed cropping system under different seed rates

Treatments	Total cost of production (Tk.)	Total income (Tk.)	Net return (Tk.)	BCR
T_1	54206.50	94200.00	39993.50	1.74
T_2	41611.50	83200.00	41588.50	1.99
T_3	54062.25	94800.00	40737.75	1.75
T_4	53917.75	99200.00	45282.25	1.84
T_5	53773.25	114800.00	61026.75	2.14
T_6	53628.90	90000.00	36371.10	1.68
T_7	53484.50	76100.00	22615.50	1.42
T_8	52390.25	80300.00	27909.75	1.53
T_9	52245.75	80700.00	28454.25	1.55
T_{10}	52101.25	89000.00	36898.75	1.71
T_{11}	51956.90	91100.00	39143.10	1.75
T_{12}	56866.50	58700.00	1833.50	1.03
$LSD_{0.05}$	1385.00	1423.00	1347.00	0.657
CV (%)	7.56	9.96	7.26	12.97

Here,

T_1 = Sole wheat
T_2 = Sole lentil
$T_3 = W_{90}\ L_{10}$
$T_4 = W_{80}\ L_{20}$
$T_5 = W_{70}\ L_{30}$
$T_6 = W_{60}\ L_{40}$
$T_7 = W_{50}\ L_{50}$
$T_8 = W_{40}\ L_{60}$
$T_9 = W_{30}\ L_{70}$
$T_{10} = W_{20}\ L_{80}$
$T_{11} = W_{10}\ L_{90}$
$T_{12} = W_{100}\ L_{100}$

Chapter 5

Summary and Conclusion

CHAPTER 5

Summery and Conclusion

The experiment was conducted at Agronomy field of Sher-e-Bangla Agricultural University (SAU) during the period from November, 2006 to March, 2007 to study the intercropping lentil with wheat at different fertilizer doses and seed rates. Twelve treatments were included in the study. In addition to each of the sole crops, different rates of wheat and lentil seeds (10 – 100% of the recommended) were tested. The experiment was conducted in randomized complete block design (RCBD) with three replications.

The results showed that some of the crop characters such as plant height, number of tillers plant^{-1} or branches plant^{-1}, dry weight plant^{-1}, 1000-seed weight and yield of both wheat and lentil were significantly affected due to seed rates.

The highest plant height of wheat was shown in sole crop. But in the intercropping treatments, the higher plant height (94.21 cm) of wheat was shown in the treatment of 90% wheat + 10% lentil at harvest.

The maximum number of tillers plant^{-1} of wheat was shown in sole crop. But in the intercropping treatments, the higher tillers plant^{-1} (5.40 and 5.20) of wheat was recorded in the treatment of 90% wheat + 10% lentil and 70% wheat + 30% lentil at harvest likewise, the highest number of branches plant^{-1} of lentil was shown in sole crop. But in the intercropping treatments, the higher branches plant^{-1} (4.33 and 4.11) of lentil was recorded in the treatment of 10% wheat + 90% lentil and 20% wheat + 80% lentil of harvest.

Number of spikes plant^{-1}, spike length, number seeds spike^{-1} of wheat was significantly affected by intercropping system. The highest number of spikes plant^{-1}, spike length, number of seeds spike^{-1} of wheat was observed in the sole treatment. But in intercropping treatments, number of spikes plant^{-1}was the highest (5.4) in the treatment of 90% wheat + 10% lentil which was similar with 70% wheat + 30% lentil. But incase of spike length (12.14, 12.11 and 12.09 cm) and number of seeds spike^{-1} (14.85, 14.73 and 14.61) were obtained from the treatments of 90% wheat + 10% lentil, 80% wheat + 20% lentil and 70% wheat + 30% lentil respectively at recommended fertilizer dose of wheat in both cases and the results were statistically similar to sole wheat treatment.

Number of flowers plant^{-1}, number of pods plant^{-1} and pod weight plant^{-1} of lentil were significantly affected by intercropping system. The highest number of flowers plant^{-1} (8.22) at 60 DAS, number of pods plant^{-1} (39.77) and pod weight plant^{-1} (1.75 g) were recorded in sole crop at the time of harvest. But in the intercropping treatments 10% wheat + 90% lentil showed the best results of number of flowers plant^{-1} (7.67), number of pods plant^{-1} (30.77) and pod weight plant^{-1} (55 g), respectively.

The highest dry weight plant^{-1} and 1000-seed weight of wheat and lentil were shown in the treatment of sole crops of both crops. But in the intercropping treatments, the highest dry weight plant^{-1} and 1000-seed weight of wheat (18.59 g and 42.87 g, respectively) were achieved from treatment of 90% wheat + 10% lentil and 70% wheat + 30% lentil. But incase of lentil those were (3.20 g and 22.41 g, respectively) which at per with 10% wheat + 90% lentil.

Grain yield of wheat was influenced by intercropping compared to the sole crop of wheat. The highest grain yield of wheat (3.14 t ha^{-1}) was obtained in monoculture. While intercropped with lentil, the highest yield of wheat (2.92 t ha^{-1} was obtained from the treatment of 90% wheat + 10% lentil. The treatments, 80% wheat + 20% lentil and 70% wheat + 30% lentil showed the yield of 2.88 and 2.84 t ha^{-1} respectively. The yield of lentil (0.91 t ha^{-1}) with the treatments of 10% wheat + 90% lentil proved the best where sole lentil gave 1.04 t ha^{-1}. But considering the combined yield the treatment of 70% wheat + 30% lentil gave the best result (3.21 t ha^{-1}) where the lowest combined yield was achieved (1.34 t ha^{-1}) from the treatment of 100% wheat + 100% lentil.

The higher productivity performance of wheat and lentil intercropping was obtained with the land equivalent ratio (LER), benefit : cost ratio (BCR) and total net return. The highest LER and BCR value of 1.30 and 2.14 respectively were obtained with the treatment 70% wheat + 30% lentil. The highest net return (61026.75 Tk. ha^{-1}) was also obtained with the same treatment.

Thus the results obtained from this study exhibited that the mixed cropping system gave encouraging results in respect of yield productivity performance. Considering wheat as the main crop, intercropping treatment of 70% wheat + 30% lentil emerged out as the promising intercropping system in terms of total return.

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Appendices

APPENDICES

Appendix I. Physical and chemical characteristics composition of soil of the experimental plot

Soil Characteristics	Analytical results
Agrological Zone	Madhupur Tract
P^H	5.46 – 5.61
Organic matter	0.80
Total N (%)	0.41
Available phosphorous	21 ppm
Exchangeable K	0.42 meq / 100 g soil

Source: Soil Resources Development Institute (SRDI)

Appendix II. Monthly average air temperature, relative humidity, rainfall and sunshine hours during the experimental period (November, 2006 to March, 2007) at Sher - e - Bangla Agricultural University campus.

Month	Year	Monthly average air temperature (^{0}C)			Average relative humidity (%)	Total rainfall (mm)	Total sunshine (hours)
		Maximum	Minimum	Mean			
November	2006	29.21	16.52	22.86	73.09	Trace	214.38
December	2006	27.25	14.81	21.03	71.05	Trace	211.50
January	2007	25.18	17.29	21.24	73.90	4.10	194.00
February	2007	30.32	18.40	24.36	67.78	3.20	226.50
March	2007	33.32	21.00	27.16	68.13	3.79	223.30

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

Appendix III Rate of different input and output cost

A. Rate of input cost

Sl. No.	Description	Rate
1.	Ploughing with tractor	Tk. 900.00 ploughing^{-1}ha^{-1}
2.	Labour	Tk. 100.00 labour^{-1} day^{-1}
3.	Fertilizer	
	i. Compost	Tk. 400.00 ton^{-1}
	ii. Urea	Tk. 6.50 kg^{-1}
	iii. TSP	Tk. 40.00 kg^{-1}
	iv. MP	Tk. 35.00 kg^{-1}
	v. Gypsum	Tk. 12.00 kg^{-1}
4.	Seeds (for sowing)	
	i. Wheat	Tk. 40.00 kg^{-1}
	ii. Lentil	Tk. 90.00 kg^{-1}
5.	Insecticide	Tk. 400.00 ha^{-1}
6.	Irrigation	Tk. 1000.00 irrigation^{-1}
7.	Interest of total input cost	12%
8.	Interest of cost of land	12%
9.	Miscellaneous	Tk. 1000.00 ha^{-1}

B. Rate of output (benefit)

Sl. No.	Description	Rate (Tk./kg)
1.	Wheat (grain)	30
2.	Lentil (grain)	80