GROWTH AND YIELD VARIATIONS IN MUSTARD AND LENTIL UNDER INTERCROPPING SYSTEMS

KANIZ SHARMIN

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA - 1207

JUNE, 2018

GROWTH AND YIELD VARIATIONS IN MUSTARD AND LENTIL UNDER INTERCROPPING SYSTEMS

By

KANIZ SHARMIN

Reg. No. 12-04994

Submitted to the Department of Agronomy
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
AGRONOMY

SEMESTER: JANUARY - JUNE, 2018

APPROVED BY:

....	....
Prof. Dr. Md. Fazlul Karim	**Prof. Dr. Md. Shahidul Islam**
Supervisor	**Co-supervisor**

....

Prof. Dr. Md. Shahidul Islam
Chairman
Examination Committee

CERTIFICATE

This is to certify that the thesis entitled ***"GROWTH AND YIELD VARIATIONS IN MUSTARD AND LENTIL UNDER INTERCROPPING SYSTEMS"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural Universitsy, 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* ***KANIZ SHARMIN, Registration No.: 12-04994,*** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

Dated:
Dhaka, Bangladesh

Prof. Dr. Md. Fazlul Karim
Supervisor
Department of Agronomy
Sher-e-Bangla Agricultural University
Dhaka-1207

Dedicated to

My Beloved Parents

ACKNOWLEDGEMENT

Alhamdulillah, all praises are due to Almighty Allah Rabbul Alamin for his gracious kindness and infinitive mercy in all the endeavors to author to let her complete the research work and the thesis succesfully.

The author would like to express her heartfelt gratitude and most sincere appreciations to her Supervisor, Prof. Dr. Md. Fazlul Karim, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his valuable guidance, advice, immense help, encouragement and support throughout the study. Likewise grateful appreciation is conveyed to Co-Supervisor Prof. Dr. Md. Shahidul Islam, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his constant encouragement, cordial suggestion, constructive criticsms and valuable advices to complete this thesis.

The author also express her deepest respect and boundless gratitude to all the respected teachers of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for their co-operation, valuable teaching and inspiration throughout the course of study and research work.

The author is also thankful to Hasan, Jasmin, Shilla for their help during experimentation. Special thanks to all other friends for their support and encouragement to complete this thesis. The author is grateful to her parents, brothers and other relatives for their support and encouragement and cordial love during the study.

Finally the author appreciates the assistance rendered by the staff of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka who have helped her during the period of experimentation.

The author

GROWTH AND YIELD VARIATIONS IN MUSTARD AND LENTIL UNDER INTERCROPPING SYSTEMS

ABSTRACT

An experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, during November 2017 to February 2018 to assess growth and yield variations of mustard and lentil under intercropping systems. Twelve treatment combinations were T_1 = Sole Mustard, T_2 = Sole Lentil, T_3 = 50% Mustard + 50% Lentil, T_4 = 1 Row Mustard + 1 Row Lentil, T_5 = 1 Row Mustard + 2 Rows Lentil,T_6 = 2 Rows Mustard + 1 Row Lentil, T_7 = 2 Rows Mustard + 2 Rows Lentil,T_8 = 3 Rows Mustard + 1 Row Lentil, T_9 = 3 Rows Mustard + 2 Rows Lentil, T_{10} = 70% Mustard + 30% Lentil, T_{11} = 80% Mustard + 20% Lentil, T_{12} = 90% Mustard + 10% Lentil. The experiment was conducted in Randomized Complete Block design with three replications. The experimental materials were Mustard (BARI Sharisha-16) and Lentil (BARI Masur-7). Seeds of these crops were sown on 1 November 2017 and harvested on 31 january 2018. Growth, yield, productivity and economic performance were studied. Results revealed that, intercropping system significant by effect on plant height, above ground dry matter plant^{-1}, length of branch, pod branch^{-1}, 1000 grain weight, grain yield and harvest index of mustard. It also significantly changed plant height, branches plant^{-1}, above ground dry matter plant^{-1}, 1000 seed weight, seed yield (t ha^{-1}) and harvest index of lentil. Intercropping reduced the sole mustard yield but economic analysis showed highest gross return (Tk. 213600 ha^{-1}), net return (Tk. 103680 ha^{-1}), and monetary advantage (Tk.87952.94 ha^{-1}) were obtained from T_4 (One row mustard with one row lentil) which was an agronomic advantage compensating the yield losses in mustard under intercropping system. The higher economic values eventually determined the maximum benefit-cost ratio (1.94) compared with BCR (1.61) for mustard normal planting. In this intercropping system, one row mustard with one row lentil showed better compatibility than other when mustard and lentil are intercropped.

CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

ACRONYMS

AEZ	=	Agro- Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BARI	=	Bangladesh Agricultural Research Institute
BCR	=	Benefit Cost Ratio
Cm	=	Centi-meter
CV (%)	=	Percentage of Coefficient of Varience
^0C	=	Degree centigrade
DAS	=	Days After Sowing
et al.	=	And others
etc.	=	Etcetra
g	=	gram (s)
Ha	=	Hectare
HI	=	Harvest Index
Kg	=	Kilogram
LER	=	Land Equivalent Ratio
LSD	=	Least Significant Difference
m	=	Meter
mm	=	Millimeter
m^2	=	Square meter
No.	=	Number
NS	=	Not significant
SAU	=	Sher-e-Bangla Agricultural University
t ha^{-1}	=	Tons per hectare
%	=	Percentage

Chapter 1

INTRODUCTION

As an agricultural country, most of the people of Bangladesh live on agriculture. Bangladesh is also an over populated country but the land area is limited with small farm holdings. Increasing agricultural production per unit of land area 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.

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

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

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

Intercropping is a traditional practice in Bangladesh. It increases total productivity per unit area through maximum utilization of land, labor and growth resources. Intercrop association simply intercropping can be defined as the production or growing of two or more crops simultaneously in the same piece of land (Ofori and Stern, 1987). It is a simple but inexpensive strategy and has been recognized as a potentially benefited technology for increase crop production (Awal *et al.,* 2006). It is an age-old practice of crop production in Bangladesh, India, China, Taiwan, Sri Lanka, Malaysia, Hong Kong, Vietnam, Africa and Latin America. It can ensure substantial yield advantages as compared to sole cropping (Rao and Singh, 1990). It becomes an urgent need to bridge the gap by increasing the production of oilseed and pulses.The present day intercropping is production oriented and requiers fairly a good level of management and input. The intercropping provided greater stability and income too. Such advantages are more under poor growing condition (Willey,1981). The yield advantage under intercropping mainly due to improved production, utilization of photosynthetically active radiation, improved water use efficiency and nutrient recycling (Rao and Willey,1980). Cop production can be intensified through intercropping (Zandstra, 1979). In agriculture, several studies on intercropping have been carried out to evaluate potential agronomic and economic benefits (Hauggaard *et al.,* 2001).

Crop compatibility is the most essential factor in a feasible intercropping system. Thus, the success of any intercropping system depends on the proper selection of crop species where competition between them for light, space, moisture and nutrients is minimized (Fukai and Trenbath, 1993). On the other hand, selection of proper crop species in an intercropping could enhance the scope of increasing in overall production per unit of land and time (Midmore, 1993). Yield advantage occurs because growth resources such as light, water, and nutrients by the intercrop over time and space as a result of differences in competitive ability for growth resources between the crops in characteristics such as rates of canopy development, final canopy size, photosynthetic adaptation of canopies to irradiance conditions and rooting depth (Midmore, 1993; Tsubo *et al*., 2001). Therefore this experiment was carried out to asses the compatibility of oilseed and pulses.

Pulses are one of the vital ingredients in the diet list of the majority of the people in Bangladesh which contains about twice as much protein as cereals (Elias, 1986; Das *et al.,* 2016). Apart from this, pulses have the capability to fix nitrogen and adding organic matter to the soil as it is one of the essential factors in sustaining soil fertility (Senanayake *et al.,* 1987). Lentil stands1st in terms of area and consumers' preference in Bangladesh (Rahman *et al.,* 2012). It is a popular edible crop among all pulses which contains 59% carbohydrate, 25% protein, and 0.7% fat (Afzal *et al.,* 1999). On the other hand, supply and demand gap of edible oils is big that has been met through importing that incurs a lump sum amount of foreign exchange every year (Bangladesh Bank, 2012). Bangladesh is producing about 0.36 million tons of edible oil per year where the total amount of oil requirement is 1.4 million tons (Mallik, 2013). Import cost of mustard oil has increased from BDT 2.42 million in 2006 to BDT 50.59 million in 2014, which is extremely high (BBS, 2016). In fact, mustard alone covers 80% of the total area under oilseed crops (Miah *et al.,* 2015). It attains first position among oilseed crops in terms of both area & cultivation. It is well known for its versatile uses. Oil-cake is used as both organic fertilizer and cattle feed and dry plant is also used as fuel (Hamjah, 2014). Bangladesh imported about

181,387 metric ton of lentil worth Tk. 1,133 crore and 2,539 metric ton of mustard worth Tk. 33 crore from abroad in 2014- 2015 (BBS, 2015). So, it is very important to produce more pulses and oilseeds domestically. Proper row arrangement of lentil and mustard under intercropping system can ensure higher productivity and economic return from same pice of land. It is observed that, some farmers of Noakhali region specially Panchgachia, Feni cultivate lentil as a mixed crop without any row arrangement thus not achieving the benefit of intercropping. Mixed cropping is the agricultural practice of growing two or more crops in the same piece of land area at the same time (Andrews and Kassam, 1976; Ofori and Stern, 1987; Anil et al., 1998).It offers effective weed suppression, pest and disease control and use of soil resources under organic farming systems (Jensen 1996). Mixed cropping reduces the risk of total crop failure as two or more different crops are cultivated simultaneously in the same field.

Lentil is one of the important pulse crops. Like other pulse crops, lentil is known for biological nitrogen fixation and thereby improves soil health, particularly in poorer areas, as well as human health by providing protein-rich grains. Due to demand of land for other uses cropped land area in the world is not going to increase. However, human population is increasing day by day, thereby demanding more food production including from pulses such as lentil. Therefore, there is a need to increase cropping intensity by including lentil in different cropping systems with intercropping. The present study is, therefore, undertaken to verify the agronomic and economic performance of mustard with lentil under intercropping systems in respect to their row arrangements over their sole cropping.

Objectives of this research work are -

1. To determine the growth and yield variations of lentil and mustard as intercrop

2. To determine the total productivity of intercrop compare to sole crop

3. To asses the compatibility between mustard and lentil as intercropping combination

4. To determine the economical advantage of intercropping

Chapter 2

REVIEW OF LITERATURE

In this chapter an attempt has been made to show a brief review of research in relation to intercropping of mustard with lentil to get better yield. Intercropping is advantageous for the farmers. It increases total production, act as insurance against crop failure of the principle crop and better utilization of resources. It reduces cost of cultural operation and increases the fertility of soil. It gives higher land equivalent ratio and higher equivalent yield.

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

The farmers demonstrated different types of intercropping and mixed cropping. The common mixture comprised of a dwarf and tall type of a legume and a non-legume. Grasspea is popular choice of the farmers for mixed cropping with cereals and oil seeds such as wheat, barley, grain sorghum, mustard, linseed or safflower (Agrikar, 1979).

Woolley and Davis (1991) reported that in intercropping system, all the environment resources utilized to maximize crop production per unit area per unit time and risk may be minimized.

Mashingaidze (2004) found that by intercropping land was effectively utilized and yield was improved.

Willey and Reddy (1981) reported that intercropping gives a greater stability of yield over monoculture.

Anil *et al*. (1998) showed that intercropping was more productive than sole crop grown on the same area of land.

Agboola and Fayemi (1971) point out that through a number of studies, it was revealed that intercropping covered the risk of crop failure, earned more profit, stabilized production, increased soil fertility and conserved soil moisture. It also increased total yield and returns in terms of per unit land.

Barker and Blamey (1985) and Singh *et al*. (1986) concluded that legume non legume intercropping increases total grain and nitrogen yield .

Seran and Brintha (2009) said that intercropping occupies greater land use and thereby provides higher net returns.

Kalra and Gangwar (1980) reported that intercropping helps in increasing farm income on sustained basis.

Ahmad and Rao (1982) reported that intercropping commonly gave greater combined yields and monetary returns than obtained from either crop grown alone.

Trenbath (1993) noted that pest and diseases were high in monocropping compared to intercropping.

Seran and Brintha (2010) showed that Intercropping have the potentials to give higher yield than sole crops, greater yield stability and efficient use of nutrients.

Rao and Willey (1980) showed a clear variation in duration of maturity of component crop was due to largely the advantage in yield, which clearly allowed in this combination for a good resource use with time.

Li *et al.* (2001) reported that in comparison to sole cropping yield benefit have been recorded in many intercropping system, including: maize/bean, sorghum/soybean, maize/cowpea, wheat/mungbeans, wheat/chickpea, maize/fababeans etc and most published intercropping mixture with significant yield advantage were from legume/non legume combination.

Fininsa (1997) showed that yield advantages in maize based intercropping were reported in Ethiopia that LER for intercrop was far above that of monocrop with maximal relative yield advantage of 28%.

A study of intercropping pigeonpea and cotton found that LER advantages in the intercropping system were the result of improved insect control in the intercroppingn treatments and not complementarity between the two plant species (Potdar *et al.* 1994).

Allen and Obura (1983) reported that in maize + cowpea/soybean intercropping system, the yield advantages ranged from 22 to 32 per cent based on LER method 19 to 25 per cent based on ATER method over sole crops and thus LER productivity estimates were greater than that of ATER .

Singh (1981) concluded that the intercropping of wheat with chickpea, lentil or grasspea 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.

Morris and Garrity (1993) reported no significant differences in total water uptake between intercrops and sole crops, but WUE by intercrops ranged from 18% to 99% greater than in sole crops. Mechanisms they propose as being responsible for increased WUE include: (a) capture of a larger portion of evapotranspiration (ET) as transpiration by intercrops; (b) interception of more light by intercrops; (c) greater efficiency in dominant species components; (d) higher transpiration efficiency by crop mixtures; and (e) reduced boundary layers in the "rough" canopy of intercropping patterns (compared with uniform canopies of monoculture).

The spatial arrangement of crops helps in the effective utilization of land, soil moisture, nutrients and solar radiation. This is brought about by choosing appropriate crops of varying morpho-physiological nature and planning their planting geometry to reduce mutual competition for resources and enhance complementarities to increase overall productivity. In general, this is achieved by intercropping systems (Waghmare *et al.,*2005).

Trenbath (1976) reported that both photosynthesis and plant growth of each component crop will be proportional to the amount of radiation that each component intercepts. There are both temporal and spatial ways in which multiple cropping systems use light more efficiently than sole crops. A mixture of crops may cover the ground over a greater portion of the year and thus intercept more light.

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

Mugabe *et al.* (1982) noted intercropping controlled weed effectively and reduce the harvestable biomass.

Banik *et al*. (2006) concluded that intercropping wheat and chickpea increase total productivity per unit area, improve land use efficiency and suppress weeds, a menacing pest in crop production.

Many scientists have reported that legume may benefit the associated non-legume crops (Waghmare *et al.,* 2005). Inclusion of legumes in the intercropping system was likely to be beneficial as they could fix atmospheric nitrogen into the soil and help in the utilization of soil moisture from deeper soil layers (Bautista, 1988).

Ghaley *et al.* (2005) concluded that in intercropping of mustard and lentil, intercropping increased total dry matter (DM) and N yield, grain DM and N yield, grain N concentration, the proportion of N derived from symbiotic N2 fixation, and soil N accumulation.

Srivastava *et al*. (2007) reported that Intercropping had a higher economic advantage over sole cropping . Lentil + mustard under 6:1 and 6:2 intercropping recorded higher net returns and benefit: cost ratio (1.63 and 1.62) than the other row ratios indicating superiority of lentil as intercrop.

Patra (1994) concluded that the mustard and lentil intercropping system recorded significantly superior values of LAI and crop growth rate (CGR) than that of the sole mustard cropping system .

Singh (1999) observed that higher lentil grain equivalent yield under mustard + lentil intercropping systems might be due to efficient utilization of resources and less competition between the component crop species.

Singh. (2009) recorded that siliqua length, number of seed siliqua^{-1} and 1000-seed weight remained unaffected due to various intercrop row ratios with lentil, but significantly higher number of siliquae plant^{-1} was in all row ratios of brown sarson + lentil intercropping compared to sole crop.

Rathore (1998) and Khushu (2001) found the moisture conservation practices brought about an improvement in water use efficiency of the mustard + lentil intercropping system as compared to control, this was due to the increment in moisture stored by moisture conservation practices and increased availability of soil moisture and also because of the reduction in evapotranspiration losses under mulching.

Tiwari (1992) observed that seed and straw yields of the lentil intercrop decreased under the mustard and lentil intercropping system owing to less plant population per unit area and more shading effect of tall growth habit of mustard leading to lower values of growth and yield attributes such as dry matter accumulation, crop growth rate, pods per plants, seed weight per plant, seeds per pod and 1000-seed weight and caused 74.4 and 64.3% reduction in seed and straw yield of the lentil intercrop over the sole lentil, respectively.

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

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

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

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

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

Oleksy and Szmigiel (2002) reported that mixed or intercropping has been 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.

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

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

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

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

Threnbath (1974) reported that the main advantage for the use of legumes in intercropping and mixed cropping is as the saving of N-fertilizer. Hashem (1983) indicated that 40 percent N may be saved in a maize + cowpea intercropping system.

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

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

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

Dwivedi *et al*. (1998) reported that all intercropping systems had higher total yield and net returns than pure stands. Higher equivalent yields were obtained with intercropping. The land equivalent ratio (LER) values were found to be greater than unity.

Bautista (1988) observed that legumes grown as cofixation. 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.

Nazir, *et al*. (1997) reported all the intercropping systems were to gave substantially higher total yield equivalent than that of sole crop.

Sarno *et al*. (1998) stated that higher equivalent yields were obtained with intercropping. Land equivalent ratio (LER) values were found to the greater than sole cropping.

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

Trenbath (1974) concluded that the combination of a leguminous species with a non-leguminous one might be expected to generate yield advantages over sole cropping ,since their canopy architectures are different, mustard grows with tall whereas lentil with short stature canopies.

Akter *et al*. (2004) studied the performance of mixed and intercropping of wheat and lentil and concluded that line sowing performed better than sole broadcast sowing.

They also observed that lentil, wheat mixed seed rate decreased lentil yield over sole lentil crop sown through broadcast method.

Markunder *et al*. (1997) found that the mixed cropping or intercropping of wheat with lentil increased the productivity per unit area compared to sole cropping of wheat or lentil.

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 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 (2.75) was obtained from wheat – lentil intercropping compared with a BCR of 2.35 for wheat alone.

From the above findings it is clear that the intercropping system has advantages in regards of land use, greater yield, monetary benefit etc. Intercropping of mustard in combination with lentil may be an important management to bring back them cultivation in the main land for their importance of production thus reducing their exporting cost.

Chapter 3

MATERIALS AND METHODS

This chapter represents a brief description of the experimental site, soil, climate, experimental design, treatments, cultural operations, data collection and their statistical analysis.

3.1 Location

The experiment was carried out at the Agronomy research field of Sher-e-Bangla Agricultural University (SAU), Dhaka during the period from November, 2017 to March, 2018 to study the growth and yield variations in mustard and lentil under intercropping systems.

3.2 Site Selection

The experimental field was located at 90^{o} 22' E longitude and 23^{0} 41' N latitude at an altitude of 8.6 meters above the sea level. The land was located at 28 Agro ecological zone (AEZ 28) of "Madhupur Tract" (Appendix I). It was deep red brown terrace soil and belongs to "Nodda" cultivated series. The soil was clay loam in texture having P^{H} was 5.7. Organic matter content was medium (2.35%).

3.3 Climate

Low temperature and minimum rainfall was the main feature of the rabi season. The monthly average air temperature, relative humidity and total rainfall during the study period (November to March) are shown in Appendix II.

3.4 Planting Materials

Two types of crops having dissimilar growth habits were used in this experiment. The crops were mustard (*Brassica campestris*) and lentil (*Lens culinaries*). In this experiment mustard was grown as main crop and lentil was grown as companion crop.

3.5 Plant Characteristics and Variety

3.5.1 Mustard

BARI Sarisha16 was released by Oilseed Research Centre, BARI in 2009. It is tall plant variety, silliquae are robust and each silliqua contains 9-11 seeds. Seed are brown in colour and bold and resistant to Orobanche. The variety is drought & salinity tolerant and suitable for late planting. Planting time is late October-late November and harvesting time is January-February. Crop duration is 105-115 and

Seed yield of 1.9-2.25 t ha^{-1}, Stover yield 3.60-4.0 t ha^{-1} . Suitable areas are Kustia, Jessore and Khulna.

3.5.2 Lentil

A high yielding variety of lentil namely BARI masur7 was selected as planting material. This variety was released by BARI in 2011.The height of the plant is 40 cm light green in color .The size of the leaflet is large and there is a hook at the tip of the leaf. The color of the flower is violet. The size of the seed is larger than the local variety and is more flat. The color of the seed is reddish brown and weight of 1000 seed is 18-20 g. This variety is tolerant to rust stem phylium blight. The seed contains about 24 to 26% protein. This variety completes its life cycle within 110-115 days. The average yield of this variety is 1.8 -2.3 t ha^{-1}.

3.6 Experimental Treatments

The treatments were as follows –

T_1 = Sole Mustard

T_2 = Sole Lentil

T_3 = 50% Mustard + 50% Lentil

T_4 = 1 Row Mustard + 1 Row Lentil

T_5 = 1 Row Mustard + 2 Rows Lentil

T_6 = 2 Rows Mustard + 1 Row Lentil

T_7 = 2 Rows Mustard + 2 Rows Lentil

T_8 = 3 Rows Mustard + 1 Row Lentil

T_9 = 3 Rows Mustard + 2 Rows Lentil

T_{10} = 70% Mustard + 30% Lentil

T_{11} = 80% Mustard + 20% Lentil

T_{12} = 90% Mustard + 10% Lentil

3.7 Experimental Design and Layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The experimental unit was divided into three blocks each of which represents a replication. Each block was divided into 12 plots in which treatments were applied at random. The distance maintained between two plots was 1m and between blocks was 1.5 m. The plot size was 4 m x 2 .5 m. It is mentioned here that the sole mustard was sown maintaining row spacing as 30 cm × 5 cm. The seeds were sown as continuous in each line following the seed rate. Sole lentil was sown maintaining line and plant spacing as 30 cm X 10 cm.

3.8 Details of the Field Operations

The cultural operations that were carried out during the experimentation are presented below:

3.8.1 Land Preparation

The land was first ploughed on October 25, 2017 by disc plough. It was then harrowed again on 12 and 13 November to bring the soil in a good tilth condition . The clods of the land were hammered to make the soil into small pieces. Weeds, stubbles and crop residues were cleaned from the land. Finally ploughed thoroughly with a power tiller and then laddering was done to obtain a desirable tilth and land preparation was done on october 30, 2017. The layout was done as per experimental design on October 31, 2017.

3.8.2 Fertilizer Application

For sole mustard fertilizers were applied at the rate of 100, 80, 30 and 20 kg ha^{-1} of N, P_2O_5, K_2O and S respectively (Fertilizer Recommendation Guide). Two-third urea and whole amount of other fertilizers were applied as basal dose during final land preparation and rest one-third urea was applied at flowering stage.

In case of sole lentil fertilizers were applied at the rate of 20, 40, 20 and 7 kg ha^{-1} of N, P_2O_5, K_2O and S respectively (Fertilizer Recommendation Guide). The entire amount of urea, TSP, MP & gypsum were applied as basal dose.

In case of mustard and lentil intercrop fertilizers were applied as per treatment based on the recommended rate for mustard. No additional fertilizers were applied lentil.

3.8.3 Seed Collection and Sowing

The mustard seeds were collected from mustard research centre of Bangladesh Agricultural Research Institute (BARI), at Joydebpur, Gazipur and the lentil seeds (BARI mosur-7) were collected from pulse and oil seeds center from the same institute. Seeds were treated with Vitavax 200 @ the rate of 3 g kg^{-1} of seeds and sown in line on November 1, 2017 as per experimental treatments. The recommended seed rate of mustard and lentil were 10 and 35 kg ha^{-1}, respectively. After sowing the seeds were covered with loose friable soil.

3.8.4 Weeding

Weeds were controlled through three weedings at 23, 38, 50 days after sowing (DAS). The weeds identified were kakpaya ghash, wild mustard, kanta notae, shetodron, bathua etc.

3.8.5 Irrigation

Germination of seeds was ensured by light irrigation. Two irrigations were given, first irrigation was given at vegetative stage and second irrigation was given at flowering stage. Excess water of the field was drained out.

3.8.6 Harvesting

At full maturity, mustard and lentil were harvested plot wise on March 10, 2018. Crop of each plot was harvested from 1 m^2 separately for yields. Then those were weighted to record the seed yield which was converted into t ha^{-1}.

3.9 Recording of Data

The following data of crops were collected during the study period:

3.9.1 Mustard

1. Plant height (cm)

2.Above ground dry matter (g)

3. Number of Plants $plot^{-1}$ (no.)

4. Number of main branches $plant^{-1}$ (no.)

5. Number of siliquae $plant^{-1}$ (no.)

6. Siliqua length (cm)

7. Number of seeds $silique^{-1}$ (no.)

8. 1000-seed weight (g)

9. Seed yield (t ha^{-1})

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

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

12.Harvest index (%)

3.9.2 Lentil

1. Plant height (cm)

2. Above ground dry matter plant $^{-1}$ (g)

3. Number of branches plant^{-1} (no.)

4. Number of pods plant^{-1}(no.)

5. 1000 seed weight (g)

6. Seed yield (t ha^{-1})

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

8. Harvest index (%)

3.10 Procedure of Recording Data

The data was taken at 20 days interval up to harvest.The detail outline of data recording is given below:

3.10.1 Mustard

3.10.1.1 Plant Height

Data was collected from ten plants of each plot which were selected randomly as per plot of the treatment.

3.10.1.2 Above Ground Dry Matter Palnt^{-1}

Ten plants were collected at different days after sowing (20, 40, 60, 80, 100 DAS and at harvest) and then oven dried at 70^0C for 48 hours. The dried samples were then weighed and averaged.

3.10.2.3 Number of Plants Plot^{-1}

No. of plants plot^{-1} were counted separately from each plot after uprooting

mustard plant.

3.10.1.4 Number of Branches Plant^{-1}

No. of branches plant^{-1} were counted from five plant plot^{-1}.

3.10.1.5 Number of Siliquae Plant^{-1}

Data was collected by counting siliquae number from five plants of each plot and averaged.

3.10.1.6 Length of Siliqua

Ten siliquae were selected from five plants of each plot and measured by scale to collect data.

3.10.1.7 Number of Seeds Siliqua^{-1}

Seeds of ten siliquae collected from five plants of each plot were counted and averaged.

3.10.1.8 Thousand-Seed Weight

Thousand seeds were counted carefully and weighed at proper moisture level using an electrical balance and data was recorded.

3.10.1.9 Seed Yield

Total mustard plants from harvested area of each plot were harvested, threshed and collected seeds were weighed by electric balance and then converted to tons per hectare.

3.10.1.10 Stover Yield

Stover weight was determined after threshing and sun drying plant without seed from each plot separately and converted data to tons per hectare.

3.10. 2 Lentil

3.10.2.1 Plant Height

The heights of ten plants were measured from the ground level to tip of the plants and then averaged.

3.10.2.2 Above Ground Dry Matter Plant^{-1}

Ten plants were collected at different days after sowing (20, 40, 60, 80, 100 DAS and harvest) and then oven dried at 70^{0}C for 48 hours. The dried samples were then weighed and averaged.

3.10.2.3 Number of Branches Plant^{-1}

Ten plants were collected randomly. Total number of branches from five plants were counted and then averaged.

3.10.2.4 Number of Pods Plant^{-1}

Number of pods plant $^{-1}$ was taken from ten plants separately only at harvest and then averaged.

3.10.2.5 Weight of Thousand Seeds

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

3.10.2.6 Seed Yield

Lentil was harvested randomly from 1 m^2 area of land of each plot. Then the harvested grasspea and lentil were threshed, cleaned and then sun dried up to 12% moisture level. The dried seeds were then weighted and averaged. The grain yield was converted into t ha^{-1}.

3.10.2.7 Harvest Index

Harvest index was determined by dividing the economic yield (seed yield) to the biological yield (seed + straw yield) from the same area and then multiplied by 100.

$$\text{Harvest Index (\%)} = \frac{\text{Seed yield (t/ha)}}{\text{Seed yield (t/ha)} + \text{Straw yield (t/ha)}} \text{X } 100$$

3.11 Relative Yield

Relative yield and land equivalent ratio were used for comparing intercropping treatments. To evaluate the productivity advantage of intercropping, LER was calculated. LER values were computed with the help of the following formulae (IRRI, 1973).

$$\text{Relative yield of Mustard} = \frac{\text{Intercrop yield of mustard}}{\text{Sole yield of mustard}}$$

$$\text{Relative yield of Lentil} = \frac{\text{Intercrop yield of lentil}}{\text{Sole yield of lentil}}$$

3.12 Land Equivalent Ratio

Land equivalent ratio (LER) = Relative yield of mustard + Relative yield of lentil

LER in its simplest form has been defined as the relative area of sole crops that would be required to produce the yield achieved by intercropping. An LER value of 1.25 would indicate yield advantage of 25% (Willey, 1979).

3.13 Equivalent Yield

In the intercropping system, equivalent yields were used as criteria for evaluating the productivity of yield of companion crop (lentil) in to the yield of main crop (mustard) on the basis of prevailing market price using the following formula (Anjaneynlu *et al.*, 1982).

$$\text{Mustard equivalent Yield} = \text{Ym} + \frac{\text{Yl} \times \text{Pl}}{\text{Pm}}$$

(For intercropping)

Where,

Ym = Seed yield of mustard (intercrop) (t ha^{-1})

Pm = Market price of mustard seed (Tk. 20 kg^{-1})

Yl = Seed yield of lentil (intercrop) (t ha^{-1})

Pl = Market price of lentil seed (Tk. 90 kg^{-1})

Similarly,

$$\text{Lentil Equivalent Yield} = \text{Yl} + \frac{\text{Ym} \times \text{Pm}}{\text{Pl}}$$

(For intercropping)

Where,

Ym = Seed yield of mustard t (intercrop) (t ha^{-1})

Yl = Seed yield of lentil (intercrop) (t ha^{-1})

Pm = Market price of mustard t seed (Tk. 20 kg^{-1})

Pl = Market price of lentil seed (Tk. 90 kg^{-1})

3.14 Monetary Advantage (Tk. ha^{-1})

The monetary advantages (Tk. ha^{-1}) were calculated for each component crop separately as per following formulae (Willey, 1979).

$$\text{Monetary advantages} = \text{Value of combined yield X } \frac{\text{LER} - 1}{\text{LER}}$$

Where, LER= Land Equivalent Ratio

3.15 Economic Analysis

Total number of labors used for different operations were recorded along with cost of variable inputs to compute the variable cost of different treatments. The cost and return analysis was done for each treatment on per hectare basis.

3.16 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 gross return according to the following formula:

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

3.17 Statistical Analysis

Data collected from different parameters were compiled and tabulated in proper form. Appropriate statistical analysis was made by MSTAT C computer package program and the treatment means were compared by least significance difference (LSD) at 5% level of significance.

Chapter 4

RESULTS AND DISCUSSION

The present experiment was conducted to determine the growth and yield variations in mustard and lentil under intercropping systems. Data on plant growth characters, yield contributing characters and yield were recorded to asses the trend of growth, development and yield of crops under different intercropping systems. The analysis of variance (ANOVA) of data is given in Appendices. The results have been presented and discussed under the following headings:

4.1 Mustard

4.1.1 Growth attributes of mustard

4.1.1.1 Plant height (cm)

Plant height of mustard was significantly affected by the intercropping with lentil. Plant height increased with the advancement of plant age (Table 1).

At 20 days after sowing (DAS), the tallest plant (14.00 cm) was obtained from T_6 which was statistically similar with T_5, T_7 and T_8 treatments and the shortest plant was obtained from T_3 treatment (11.40 cm).

At 40 DAS, highest plant height (63.29 cm) was obtained from T_{10} and the lowest (53.25 cm) was obtained from T_7 treatment which was statistically similar with T_4 treatment.

At 60 DAS, T_{11} treatment resulted in highest plant height (98.12 cm). The lowest plant height (83.30 cm) was obtained from T_6 treatment.

At 80 DAS, the highest plant height 92.20 cm was obtained from T_3 treatment. Whereas lowest plant height 85.66 cm was obtained from T_6 treatment.

At final harvest, the tallest plant (92.65 cm) was observed in T_4 treatment. The shortest plant (85.43 cm) was observed in T_1 treatment.

The variation in plant height of mustard under different cropping systems might be attributed for the differential availability of primary requirements like nutrient, moisture, light, space etc (Bray, 1954; Wahua, 1983; Shackel and Hall, 1984).

Table 1. Effect of intercropping on the plant height of mustard at different days after sowing

Treatments	Plant height (cm) at different days after sowing				
	20	40	60	80	At harvest
T_1	13.10 ab	47.21 c	86.39	85.89	85.43
T_3	11.40 b	63.27 a	96.95	92.20	90.65
T_4	12.50 ab	53.30 bc	86.23	87.97	92.65
T_5	13.67 a	55.73 a-c	86.98	87.72	89.39
T_6	14.00 a	57.73 ab	83.30	85.66	87.92
T_7	13.67 a	53.25 bc	86.42	89.06	87.56
T_8	14.00 a	53.93 a-c	85.47	88.11	88.85
T_9	12.67 ab	59.10 ab	91.09	89.60	89.86
T_{10}	12.53 ab	63.29 a	91.58	89.61	89.81
T_{11}	12.50 ab	62.10 ab	98.12	90.71	89.52
T_{12}	12.50 ab	60.47 ab	94.28	89.28	89.87
LSD $_{(0.05)}$	**2.06**	**9.77**	**NS**	**NS**	**NS**
CV (%)	**9.35**	**10.02**	**9.73**	**11.73**	**10.33**

T_1 = Sole Mustard
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.1.1.2 Above Ground Dry Weight Plant^{-1} (g)

Above ground dry matter weight of mustard was significantly affected by intercropping with lentil (Table 2). It increased with the advancement of plant age.

At 20 DAS, the highest dry matter of mustard (0.18 g) was obtained from T_6 treatment and the lowest dry matter (0.13 g) was obtained from T_{11} treatment.

At 40 DAS, the highest dry matter weight of mustard (2.76 g) obtained from T_{11} treatment and the lowest dry matter (2.27 g) was obtained from T_8 treatment.

At 60 DAS, the highest dry weight of mustard was obtained from T_1 (11.17 g) treatment and the lowest dry weight was found from T_{10} (7.44 g) and it was statistically similar with T_5 treatment.

At 80 DAS, the maximum dry weight of mustard was obtained from T_{12} treatment (8.87 g). The minimum dry matter was obtained from T_3 treatment (7.46 g).

Table 2. Effect of intercropping on the above ground dry matter weight $plant^{-1}$ of mustard at different days after sowing

Treatments	Above ground dry matter weight $plant^{-1}$ (g) at different days after sowing			
	20	40	60	At harvest
T_1	0.13 de	2.41 ab	11.17 a	7.94
T_3	0.15 b-d	2.55 ab	9.08 b	7.46
T_4	0.13 de	2.50 ab	9.29 b	8.41
T_5	0.16 ab	2.50 ab	7.44 e	7.86
T_6	0.17 a	2.37 ab	8.78 bc	7.61
T_7	0.14 c-e	2.60 ab	7.44 e	8.65
T_8	0.14 cde	2.27 b	8.33 b-e	8.70
T_9	0.15 bc	2.50 ab	8.65 b-d	8.81
T_{10}	0.13 e	2.43 ab	7.60 de	7.7
T_{11}	0.16 ab	2.75 a	9.21 b	8.43
T_{12}	0.15 bcd	2.35 ab	7.81 c-e	8.84
$LSD_{(0.05)}$	**0.02**	**0.44**	**1.16**	**NS**
CV (%)	**9.65**	**10.36**	**7.88**	**10.36**

T_1 = Sole Mustard
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.1.1.3 Number of Branch Plant^{-1}

The number of branches per square meter of mustard was affected significantly due to different intercropping system (Table 3).

At 40 DAS, the highest number of branch was obtained from T_{11} (5.67) treatment. The lowest number of branch was obtained from T_7 (3.22) treatment which was statistically similar with T_1 treatment.

At 60 DAS, the maximum number of branch of mustard (11.33) was obtained from T_3 treatment. The minimum number of branch (8.50) was obtained from T_9 treatment.

At 80 DAS, the highest number of branch of mustard (9.94) was obtained from T3 treatment which was statistically similar with T_8. The lowest number of branch (8.21) was obtained from T_{11} treatment.

At harvest, the highest (10.47) number of branch of mustard was shown in T_3 treatment while the lowest number (8.73) from T_{10} treatment.

Table 3. Effect of intercropping on the branches plant^{-1} of mustard at different days after sowing

Treatments	Branches plant^{-1} (no.) at different days after sowing			
	40	**60**	**80**	**At harvest**
T_1	3.73 de	9.20 bc	8.73 ab	9.07 ab
T_3	4.83 b	11.33 a	9.94 a	10.47 a
T_4	4.94 b	10.17 a-c	9.66 ab	10.07 ab
T_5	3.94 d	10.17 a-c	8.56 ab	9.20 ab
T_6	4.78 bc	9.17 bc	9.44 ab	9.20 ab
T_7	3.22 e	10.17 a-c	9.31 ab	9.40 ab
T_8	4.00 d	9.50 bc	9.80 a	9.73 ab
T_9	4.17 cd	8.50 c	8.94 ab	9.67 ab
T_{10}	4.83 b	9.00 bc	9.04 ab	8.73 b
T_{11}	5.67 a	10.33 ab	8.21 b	9.33 ab
T_{12}	4.00 d	10.00 a-c	9.53 ab	10.13 ab
LSD $_{(0.05)}$	**0.62**	**1.70**	**1.58**	**1.67**
CV (%)	**8.30**	**10.23**	**10.07**	**10.29**

T_1 = Sole Mustard
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.1.2 Yield attributes and yields of mustard

4.1.2.1 Number of siliquae plant^{-1}

Intercropping mustard with lentil showed significant effect on mustard (Figure1). The maximum number of siliquae plant^{-1} (160.00) was recorded from T1 treatment and minimum (108.3) was given by treatment T12 (90% of mustard with 10% lentil).

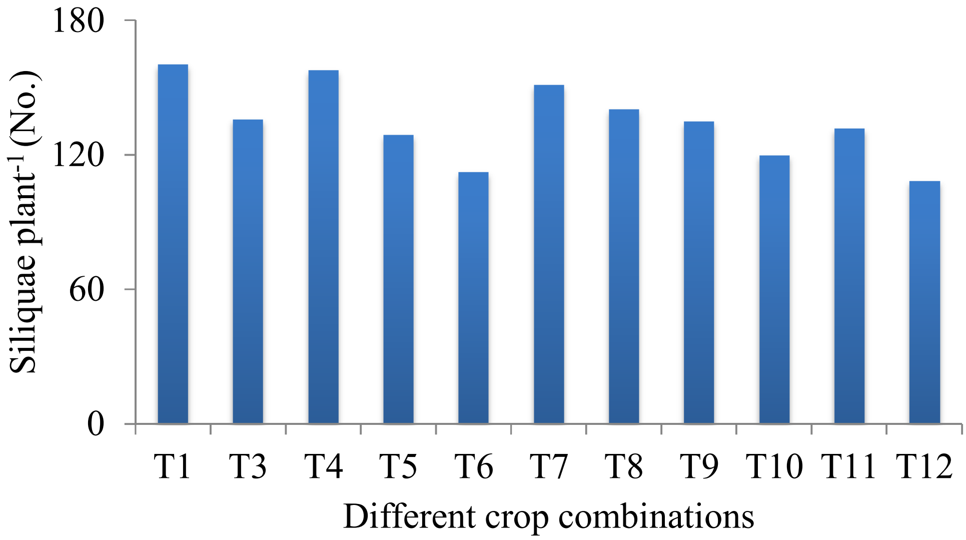


Figure 1. Effect of intercropping on the siliquae plant^{-1} of mustard ($LSD_{0.05}$ =24.61)

T_1 = Sole Mustard
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.1.2.2 Length of silique

Intercropping mustard with lentil showed no significant differences on siliqua length of mustard though the numerically maximum siliqua length (4.75 cm) was found in T_7 (Two rows of mustard two rows of lentil) and the minimum (4.41 cm) in T_3 (50% of mustard with 50% of lentil).

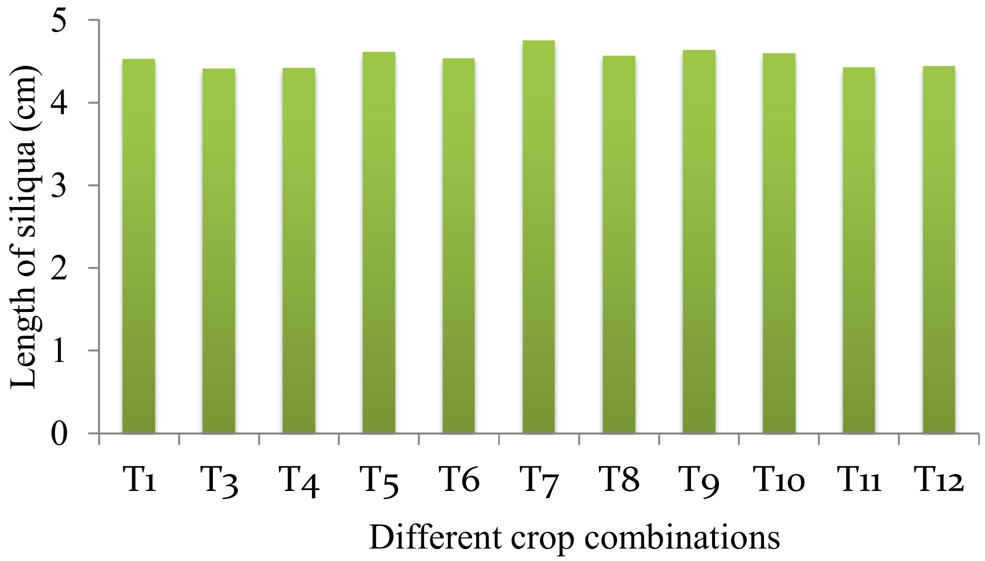


Figure 2. Effect of intercropping on the length of siliqua of mustard ($LSD_{0.05}$ = NS)

T_1 = Sole Mustard
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.1.2.3 Number of seeds siliqua^{-1}

Treatment T_3 (50% mustard and 50% lentil) was resulted the highest (21.77) no. of seeds siliquae^{-1} where other treatments showed more or less same result and the lowest (19.87) was recorded from T_8(three rows mustard with one row lentil) treatment.

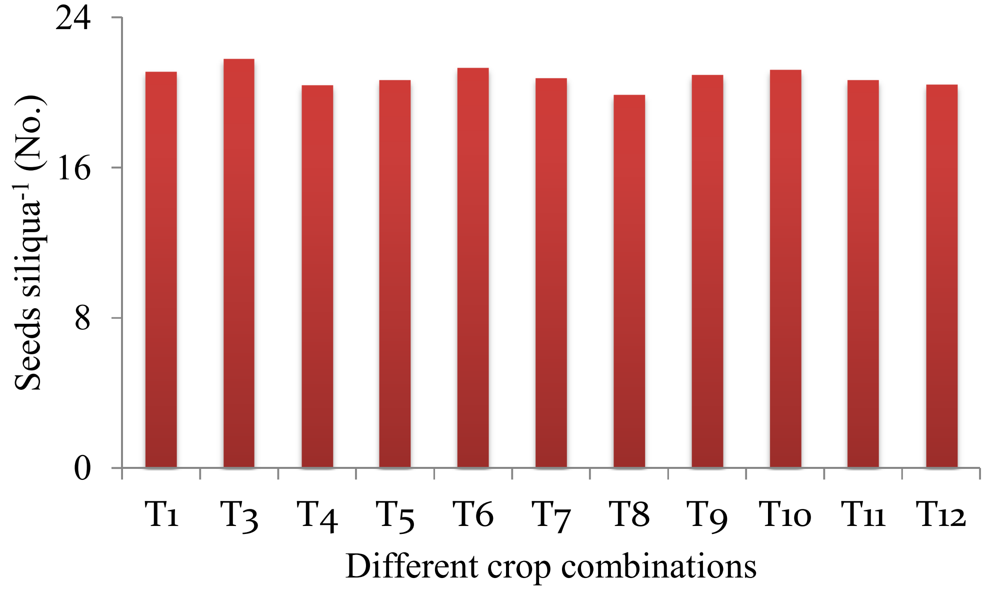


Figure 3. Effect of intercropping on the seeds siliqua^{-1} of mustard ($LSD_{0.05}$ = NS)

T_1 = Sole Mustard

T_3 = 50% Mustard + 50% Lentil

T_4 = 1 Row Mustard + 1 Row Lentil

T_5 = 1 Row Mustard + 2 Rows Lentil

T_6 = 2 Rows Mustard + 1 Row Lentil

T_7 = 2 Rows Mustard + 2 Rows Lentil

T_8 = 3 Rows Mustard + 1 Row Lentil

T_9 = 3 Rows Mustard + 2 Rows Lentil

T_{10} = 70% Mustard + 30% Lentil

T_{11} = 80% Mustard + 20% Lentil

T_{12} = 90% Mustard + 10% Lentil

4.1.2.4 Thousand-seed weight

There was no significant variation in thousand-seed weight of mustard observed when intercropped with lentil.

Sharma *et al.*(1986) conducted an experiment of intercropping mustard with wheat during winter season on a sandy clay loam soil of Pantnagar and observed that 1000-seed weight of mustard remain unaffected under intercropping system.

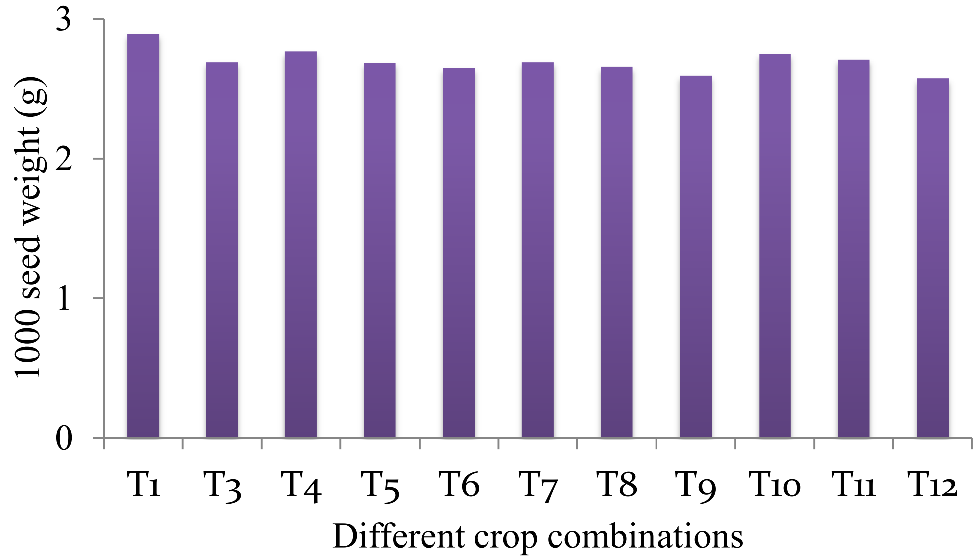


Figure 4. Effect of intercropping on the 1000 seed weight of mustard ($LSD_{0.05}$ =NS)

T_1 = Sole Mustard
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.1.2.5 Seed yield of mustard

Seed yield of mustard resulted significant differences when intercropped with lentil. Sole mustard was resulted the highest seed yield (2.54 t ha^{-1}) while among other treatments T_{12} (90%mustard with 10% lentil) resulted the lowest (1.74 t ha^{-1}) seed yield. The second highest seed yield of mustard was obtained from T_4 (2.30 t ha^{-1}) treatment (one row lentil with one row mustard). In T_1 treatment (sole mustard) intra specific competition for natural resources was lowest in comparison to intercropping systems. Therefore this gave highest yield.

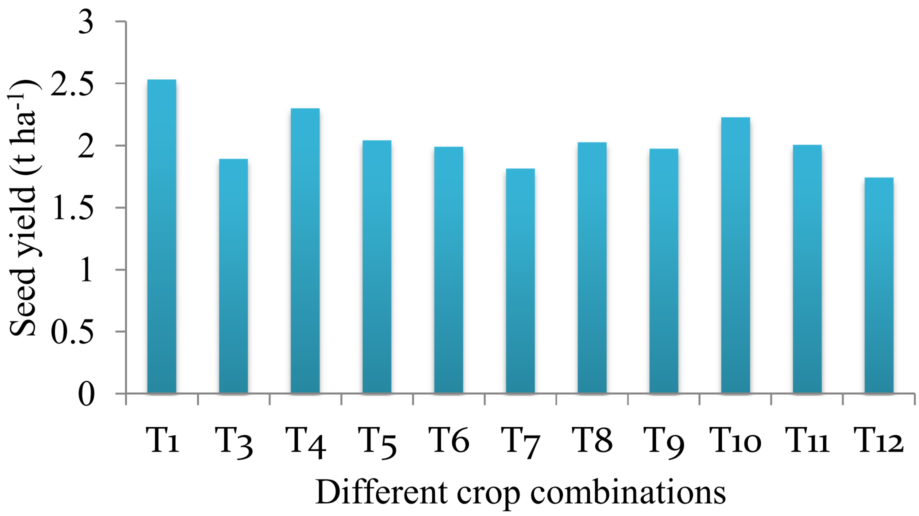


Figure 5. Effect of intercropping on the seed yield of mustard ($LSD_{0.05}$ =0.38)

T_1 = Sole Mustard
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.1.2.6 Stover yield

Significant difference was observed on stover yield of mustard in different treatments (Fig. 5). The highest stover yield of mustard was obtained from T_1 (8.41 t ha^{-1}) treatment (Sole mustard) which was statistically similar with T_{10} treatment and minimum (5.64 t ha^{-1}) was obtained from T_7 (Two rows mustard with two rows lentil) treatment.

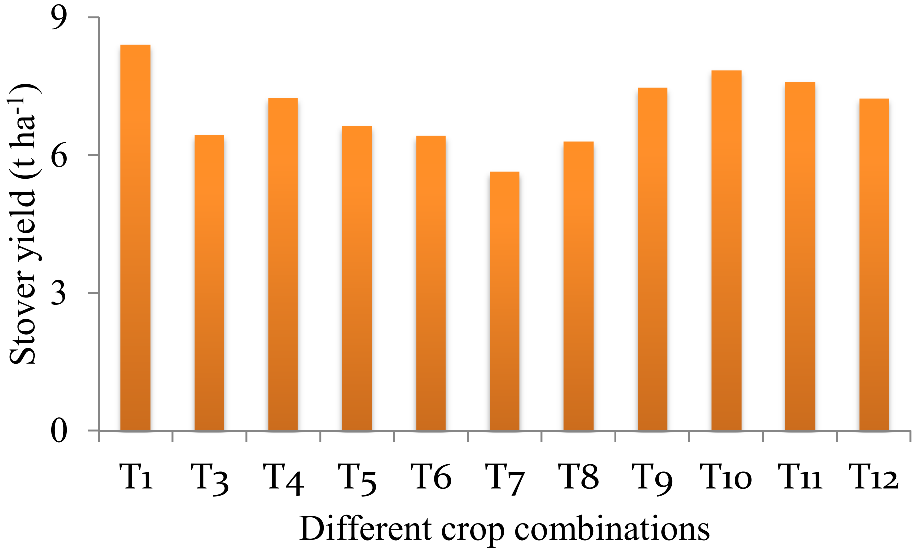


Figure 6. Effect of intercropping on the stover yield of mustard ($LSD_{0.05}$ =1.28)

T_1 = Sole Mustard
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.1.2.7 Biological yield

There was significant differences observed in biological yield of mustard where the highest (10.95 t ha^{-1}) was obtained from T_1 (Sole mustard) and the lowest (7.46 t ha^{-1}) from T_7 (Two rows mustard with two rows lentil) when intercropped with lentil. However there was less difference among other treatments (Fig.7).

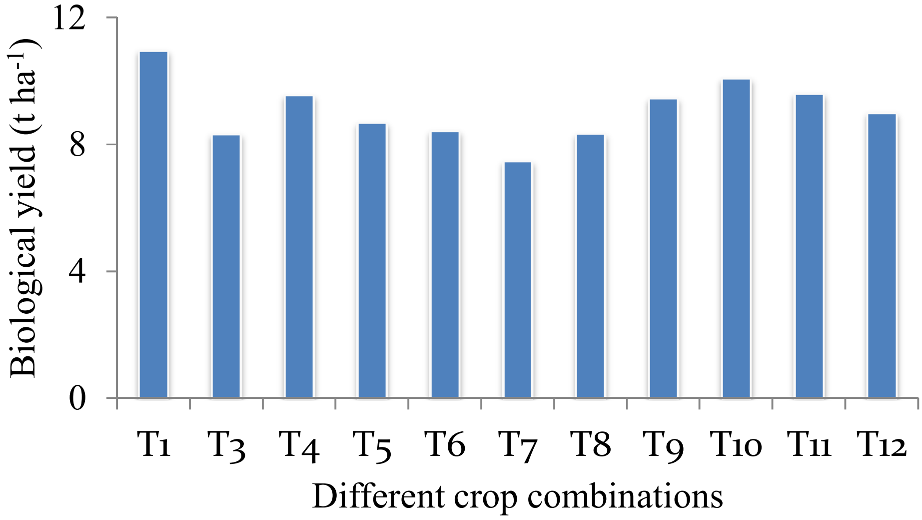


Figure 7. Effect of intercropping on the biological yield of mustard ($LSD_{0.05}$ =1.63)

T_1 = Sole Mustard
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.1.2.8 Harvest index (%)

The highest (24.45%) harvest index of mustard was given by T_8 (three rows mustard with one row lentil) and lowest (19.41%) was obtained from T_{12} (90% mustard with 10%) treatment (Fig.8).

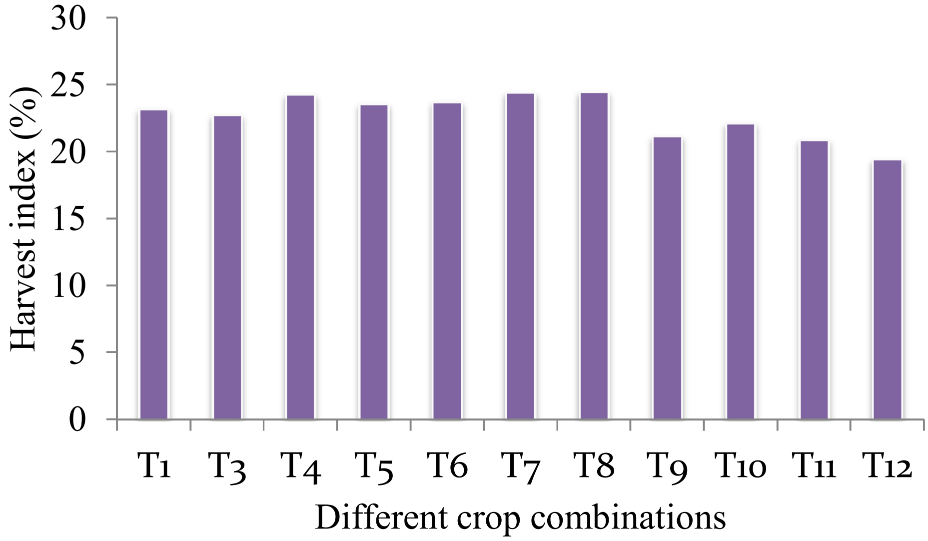


Figure 8. Effect of intercropping on the harvest index of mustard ($LSD_{0.05}$ =4.13)

T_1 = Sole Mustard
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.2 Lentil

4.2.1 Growth attributes of lentil

4.2.1.1 Plant height (cm)

Plant height of lentil varied different intercropping systems (Fig 3). Plant height of lentil increased with the advancement of plant age. At 20 days after sowing (DAS), 10.23 cm plant height was obtained from T_2 treatment (sole lentil) which was highest whereas the lowest plant height (7.67cm) was obtained from T_{11} treatment (80% mustard with 20% lentil).

At 40 DAS, tallest plant (22.47cm) was obtained from T_3treatment (50% mustard with 50% lentil). The shortest plant (17.03 cm) was obtained from T_6 treatment (Two rows mustard with one row lentil) which was statistically similar with T_2, T_8, T_7, and T_{10} treatments.

At 60 DAS, highest plant height (41.30 cm) was obtained from T_5 treatment (One row mustard with two rows lentil). The lowest plant height (29.60 cm) was obtained from T_8 treatment.

At 80 DAS, maximum plant height was 35.54 cm was recorded from T_4 treatment (One row mustard with one row lentil) and the minimum plant height 33.51cm was obtained from T_{10} treatment (70% mustard with 30% lentil).

At 100 DAS, 41.17 cm plant height was obtained from T_7 treatment (Two rows mustard with two rows lentil) which was highest and the lowest (36.04 cm) from T_{12} treatment (90% mustard with 10% lentil).

At maturity, the highest plant height (43.92 cm) was obtained from T_6 treatment (Two rows mustard with one row lentil) which whereas the lowest plant height (37.93 cm) was obtained from T_2 treatment (Sole lentil).

Table 4. Effect of intercropping on the plant height of lentil at different days after sowing

Treatments	Plant height (cm) at different days after sowing					
	20	40	60	80	100	At harvest
T_2	10.23 a	18.16 b	38.93 ab	35.31	36.67	37.93
T_3	9.83 ab	22.47 a	34.08 bc	34.03	36.72	38.57
T_4	9.83 ab	20.30 ab	35.70 a-c	37.54	38.47	40.32
T_5	9.33 a-c	19.07 ab	41.30 a	35.58	38.11	41.13
T_6	10.00 ab	17.03 b	33.73 bc	35.03	39.14	43.92
T_7	10.00 ab	18.95 ab	36.57 ab	35.04	41.17	43.42
T_8	9.00 a-d	17.14 b	29.60 c	35.59	38.84	43.90
T_9	8.17 cd	19.37 ab	34.68 a-c	35.04	37.87	40.60
T_{10}	9.33 a-c	18.33 b	35.90 a-c	33.51	38.18	42.23
T_{11}	7.67 d	20.47 ab	36.80 ab	35.32	36.67	39.44
T_{12}	8.67 b-d	20.47 ab	35.63 a-c	35.99	36.04	38.28
LSD $_{(0.05)}$	**1.53**	**3.70**	**6.69**	**NS**	**NS**	**NS**
CV (%)	**9.68**	**11.29**	**10.99**	**10.02**	**10.04**	**10.38**

T_2 = Sole Lentil
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.2.1.2 Above ground dry matter plant^{-1}

Above ground dry matter plant^{-1} of lentil was affected significantly by different intercropping systems (Table 9). At 20 DAS, highest (0.04 g) dry matter plant^{-1} of lentil was obtained from T_4treatment (One row mustard with one row lentil) which was statistically similar with T_9 treatment and lowest (0.02 g) from T_{10} treatment.

At 40 DAS, highest dry matter plant^{-1} of lentil (0.17 g) was obtained from T_4 (One row mustard with one row lentil) treatment where the lowest dry matter plant^{-1} of lentil (0.14 g) was obtained from T_8 (Tree rows mustard with one row lentil) treatments.

At 60 DAS, the maximum dry matter plant^{-1} of lentil (0.42 g) was obtained from T_4 treatment (One row mustard with one row lentil). The lowest dry matter plant^{-1} was 0.28 g was obtained from T_6, T_8, and T_{12} treatments.

At 80 DAS, the maximum dry matter plant^{-1}(1.28 g) was obtained from T_5 treatment (One row mustard with two rows lentil) which was statistically similar with T_7 and T_8 treatments. The minimum dry matter plant^{-1}(1.15 g) was obtained from T_{11} treatment (80% mustard with 20% lentil).

At 100 DAS, the maximum dry matter plant^{-1} was obtained from (3.70 g) T_4 treatment (one row mustard with one row lentil) and minimum (3.12 g) was obtained from T_9 treatment (Three rows mustard with one row lentil).

At maturity maximum dry matter plant^{-1} (3.69 g) was obtained from T4 treatment (One row mustard with one row lentil) and minimum (3.45) was obtained from T_8 and T_{11} treatments.

Table 5. Effect of intercropping on the above ground dry matter weight plant^{-1} of lentil at different days after sowing

Treatments	Above ground dry matter weight plant^{-1} (g) at different days after sowing					
	20	40	60	80	100	At harvet
T_2	0.03	0.157 a-c	0.34 bc	1.24	3.35 a	3.55
T_3	0.03	0.153 bc	0.33 cd	1.20	3.33 a	3.63
T_4	0.04	0.173 a	0.42 a	1.34	3.70 a	3.69
T_5	0.03	0.143 c	0.38 ab	1.28	3.16 a	3.62
T_6	0.03	0.157 a-c	0.28 d	1.23	3.15 a	3.51
T_7	0.03	0.153 bc	0.28 d	1.28	2.50 b	3.55
T_8	0.03	0.140 c	0.32 cd	1.28	3.25 a	3.45
T_9	0.04	0.167 ab	0.32 cd	1.19	3.12 a	3.58
T_{10}	0.02	0.163 ab	0.30 cd	1.16	3.25 a	3.50
T_{11}	0.02	0.157 abc	0.30 cd	1.15	3.19 a	3.45
T_{12}	0.03	0.150 bc	0.28 d	1.23	3.31 a	3.51
LSD $_{(0.05)}$	**NS**	**0.02**	**0.05**	**NS**	**0.60**	**NS**
CV (%)	**9.81**	**10.65**	**8.84**	**10.07**	**10.93**	**9.61**

T_2 = Sole Lentil
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.2.1.3 Branches plant^{-1} (no.)

Number of branches plant^{-1} of lentil was affected by different intercropping systems (Table 10). At 40 DAS, the highest branches plant^{-1} of lentil (5.68) was obtained from T_4 (One row mustard with one row lentil) treatment whereas the lowest number of branches plant^{-1} (3.54) was obtained from T_{10} treatment.

At 60 DAS, maximum number of branches plant^{-1} of lentil (9.42) was obtained from T_7 treatment (Two rows mustard with two rows lentil) and minimum number of branch(7.59) was obtained from T_9 treatment (Three rows of mustard with two rows lentil).

At 80, 100 DAS and at maturity the highest branches plant^{-1} was recorded from T_4 treatment (one row mustard with one row lentil) and lowest branches plant^{-1}(9 .88, 16.66, 17.80) was obtained from T_{12}, T_7 and T_{12} treatments respectively.

Table 6. Effect of intercropping on the branches plant^{-1} of lentil at different days after sowing

Treatments	Branches plant^{-1} (no.) at different days after sowing				
	40	60	80	100	At harvest
T_2	4.97 ab	8.59 a-c	10.33 b	20.03 a	20.57 ab
T_3	4.52 bc	7.67 c	10.85 ab	18.50 ab	19.33 ab
T_4	5.68 a	9.14 ab	12.67 a	20.15 a	21.59 a
T_5	5.16 ab	8.09 a-c	11.66 ab	19.63 a	20.29 ab
T_6	4.48 bc	7.95 bc	11.26 ab	18.49 ab	20.09 ab
T_7	4.50 bc	9.42 a	11.18 ab	17.80 ab	18.45 ab
T_8	4.94 ab	8.35 a-c	10.73 ab	17.98 ab	18.43 ab
T_9	3.94 cd	7.59 c	10.55 ab	18.06 ab	18.46 ab
T_{10}	3.54 d	8.12 a-c	10.78 ab	16.66 b	18.33 b
T_{11}	4.15 cd	9.25 ab	10.34 b	17.83 ab	18.33 b
T_{12}	3.94 cd	9.10 ab	9.877 b	16.71 b	17.80 b
LSD $_{(0.05)}$	**0.76**	**1.42**	**2.15**	**2.77**	**3.23**
CV (%)	**9.88**	**9.83**	**11.56**	**8.85**	**9.85**

T_2 = Sole Lentil
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.2.2 Yield and yield attributes

4.2.2.1 Pods plant^{-1} (no.)

Pods plant^{-1} was affected significantly by different intercropping systems (Figure 9). The highest number of pods plant^{-1} of lentil (101.90) was obtained from T_2 treatment (sole lentil). The lowest number of pods plant^{-1} of lentil (42.65) was obtained from T_{10} treatment (70% mustard with 30% lentil) which was statistically similar with T_9, T_{11} and T_{12} treatments.

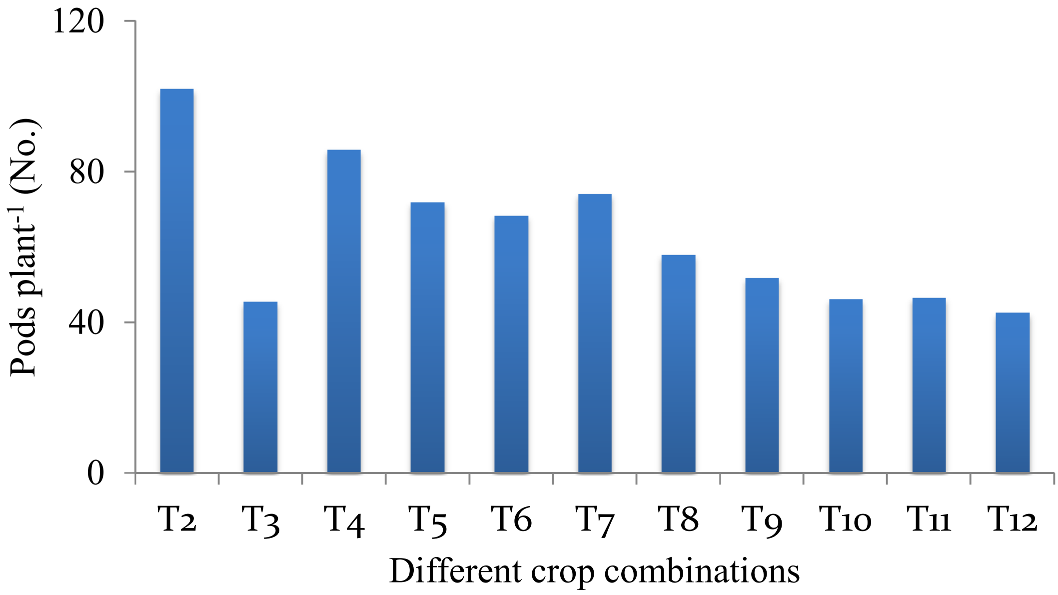


Figure 9. Effect of intercropping on the pods plant^{-1} of lentil ($LSD_{0.05}$ =10.84)

T_2 = Sole Lentil
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.2.2.2 Seeds pod^{-1}

There was no significant difference in seed pod^{-1} of lentil observed when intercropped with lentil. However highest no. of seeds pod^{-1} was obtained in T_4 treatment (One row mustard with one row lentil) where other treatment shows more or less similar result.

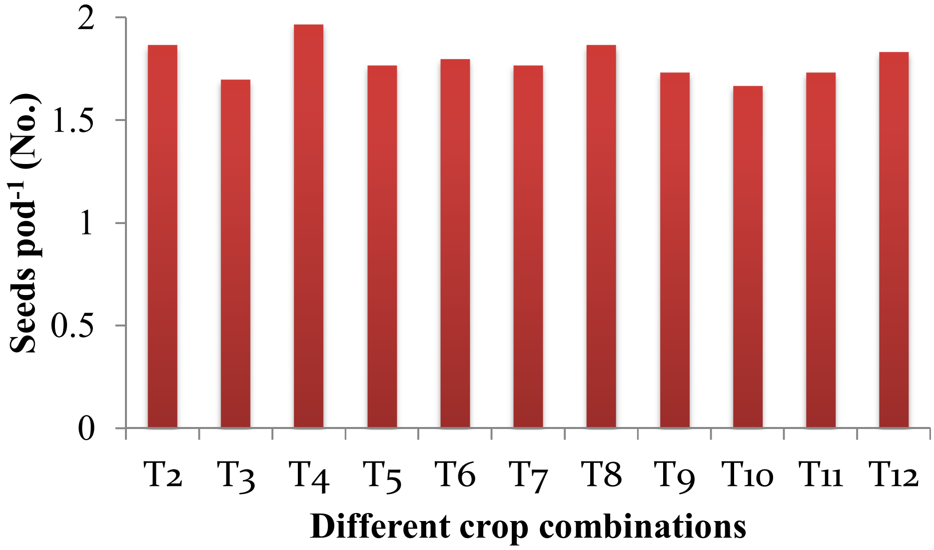


Figure 10. Effect of intercropping on the seeds pod^{-1} of lentil ($LSD_{0.05}$ =NS)

T_2 = Sole Lentil
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.2.2.3 Thousand seed weight (g)

There was no significant difference in thousand seed weight of lentil when intercropped with mustard. However the maximum thousand seed weight (21.14 g) was found from T_6 treatment (Two rows mustard with one row lentil) whereas the lowest thousand seed weight (18.51 g) was found from T_3 treatment (50% mustard with 50% lentil). Other treatment shows more or less similar result.

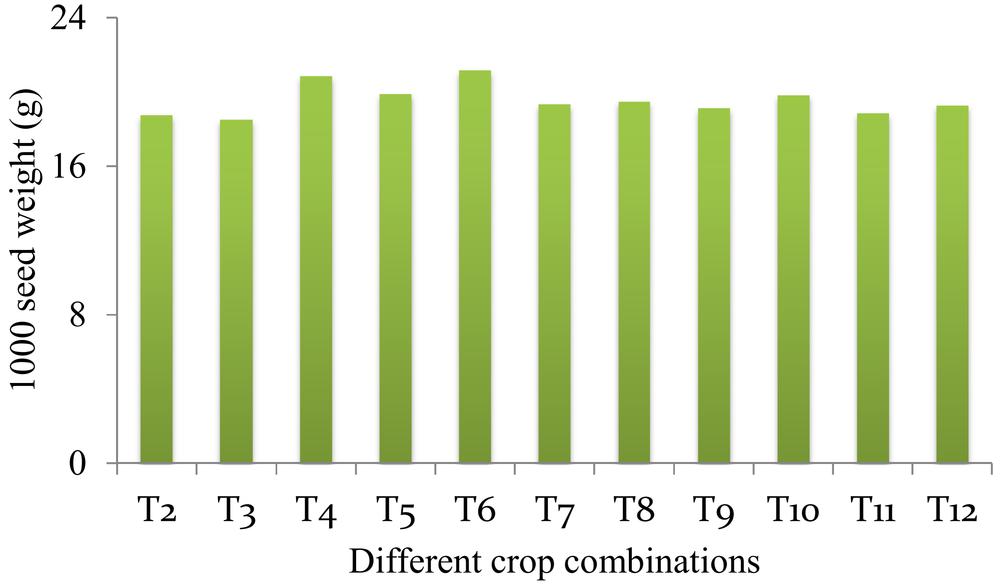


Figure 11. Effect of intercropping on the 1000 seed weight of lentil ($LSD_{0.05}$ =NS)

T_2 = Sole Lentil
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.2.2.4 Seed yield (t ha^{-1})

Seed yield of lentil varied significantly due to different intercropping systems (Fig.11). The highest (0.797t ha^{-1}) seed yield was obtained from T_2 treatment (Sole lentil) and the lowest seed yield (0.367 t ha^{-1}) was obtained from T_{12} treatment (90% mustard with 10% lentil). In T_{12} treatment 10% lentil seeds were broadcasted with 90% mustard seed. In this treatment lowest seed yield was obtained may be due to shadding effect of tall growing mustard plant and more competition for air water and other natural resources. T_2 treatment gave highest seed yield since here competition for different natural resources are less where its yield was reduced by 70 % to 80 % by different intercropping systems with mustard.

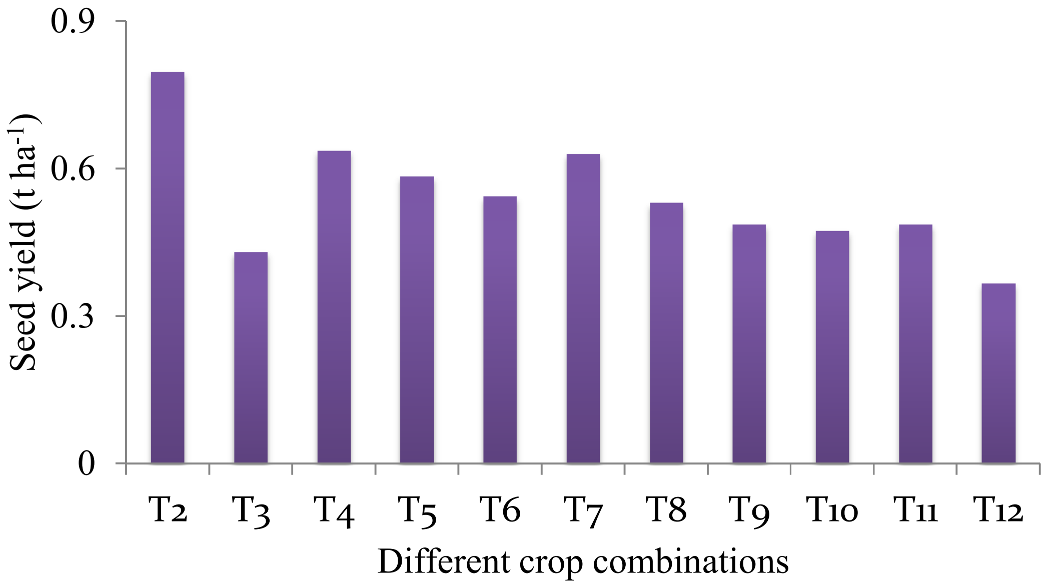


Figure 12. Effect of intercropping on the seed yield of lentil ($LSD_{0.05}$ =0.09)

T_2 = Sole Lentil
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.2.2.5 Stover yield

There was significant variations in stover yield of lentil under intercropping system with mustard. The highest stover yield was obtained T_4 (One row mustard with one row lentil) and T_7 treatment (Two rows mustard with two rows lentil) where lowest stover yield was obtained from T_{12} treatment (90 % mustard with 10 % lentil). This may be due to competition of short growing lentil with tall growing mustard.

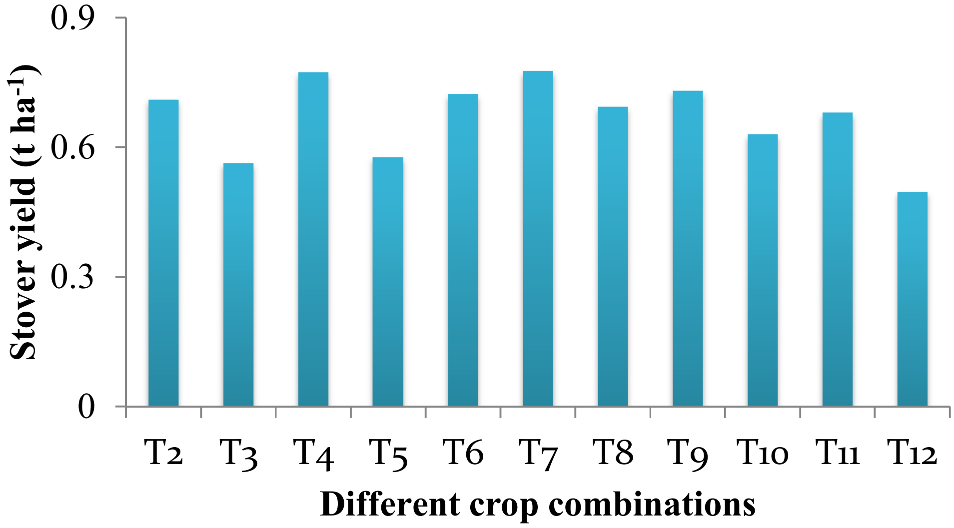


Figure 13. Effect of intercropping on the stover yield of lentil ($LSD_{0.05}$ =0.13)

T_1 = Sole Mustard	T_7 = 2 Rows Mustard + 2 Rows Lentil
T_2 = Sole Lentil	T_8 = 3 Rows Mustard + 1 Row Lentil
T_3 = 50% Mustard + 50% Lentil	T_9 = 3 Rows Mustard + 2 Rows Lentil
T_4 = 1 Row Mustard + 1 Row Lentil	T_{10} = 70% Mustard + 30% Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil	T_{11} = 80% Mustard + 20% Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil	T_{12} = 90% Mustard + 10% Lentil

4.2.2.6 Harvest index (%)

Harvest Index of lentil varied significantly due to different intercropping systems (Figure12). The maximum value of harvest index (52.85%) obtained from T_2 treatment (Sole lentil) and the lowest value (40.13%) was obtained from T_9 treatment (Three rows mustard with Two rows lentil) which was statistically similar with T_{10} ,T_{11} and T_{12} treatments.

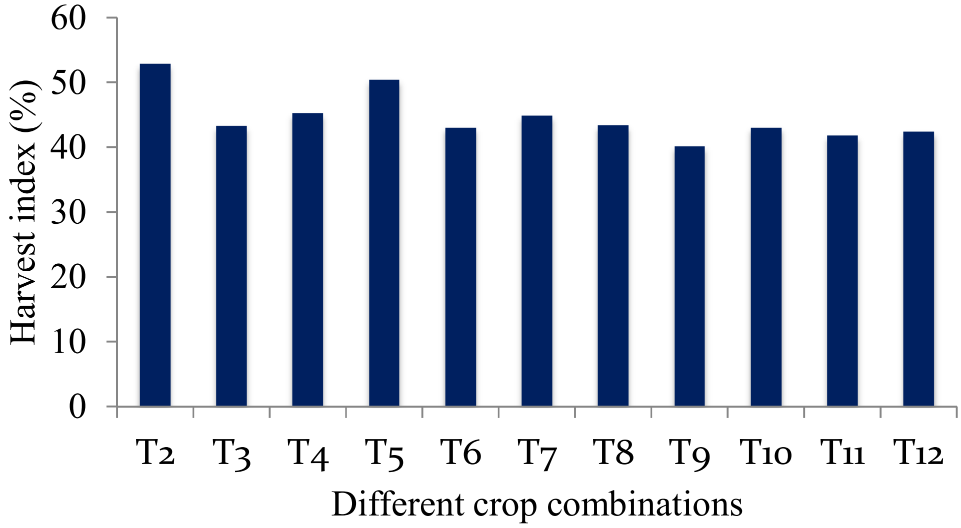


Figure 14. Effect of intercropping on the harvest index of lentil ($LSD_{0.05}$ =7.30)

T_1 = Sole Mustard
T_2 = Sole Lentil
T_3 = 50% Mustard + 50% Lentil
T_4 = 1 Row Mustard + 1 Row Lentil
T_5 = 1 Row Mustard + 2 Rows Lentil
T_6 = 2 Rows Mustard + 1 Row Lentil
T_7 = 2 Rows Mustard + 2 Rows Lentil
T_8 = 3 Rows Mustard + 1 Row Lentil
T_9 = 3 Rows Mustard + 2 Rows Lentil
T_{10} = 70% Mustard + 30% Lentil
T_{11} = 80% Mustard + 20% Lentil
T_{12} = 90% Mustard + 10% Lentil

4.3 Productivity performance

4.3.1 Relative yield

4.3.1.1 Relative yield of mustard

The relative yield of mustard varied due to different intercropping systems (Table 7). The maximum relative yield of mustard (0.91) was obtained from T_4 treatment, which was statistically similar with T_5, T_8, T_{10} and T_{11} treatments, but the lowest relative yield of mustard(0.72) was obtained from T_{12} which was statistically similar with T_3 and T_7 treatments.

4.3.1.2 Relative yield of lentil

The maximum relative yield of lentil (0.79) was obtained from T_4 and T_7 treatment where as the lowest relative yield of lentil (0.47) was obtained from T_{12} treatment (Table 7).

4.3.2 Combined yield of mustard and lentil

Combined yield obtained in intercropping systems were always higher than those obtained in sole cropping (Table 7). This increased combined yield may be due to better utilization of space, soil nutrient and moisture by both the crops. The highest combined yield (2.93t ha^{-1}) was found in T4 treatment and the lowest (2.11 t ha^{-1}) in T_{12} treatment. The second and third highest combined yield 2.70 and 2.62 t ha^{-1} was found in T_{10} and T_5 treatments, respectively. Singh *et al*. (1996) reported that the combined yield of wheat and lentil under wheat-lentil intercropping system was significantly higher than that of sole crop.

4.3.3 Land equivalent ratio (LER)

Intercropping offered significant effect on land equivalent ratio under different intercropping systems (Table 7). The highest LER value (1.70) was obtained from T_4 treatment . The LER value of 1.70 means that by intercropping 2.30 t of mustard and 0.63 t of lentil were produced from 1 ha of land instead of growing them separately in 1.70 ha of land. The second highest LER value 1.53 was obtained from T_5 treatment. The lowest LER value 1.16 was obtained from T_{12} treatment. The treatments whose LER value less than 1 have failed to show yield advantage over sole crop.

Pandita *et al.* (1998) reported that the highest LER (1.61) was found on 1:2 ratio of maize + French bean and the lowest LER (1.07) was found in maize + greengram system in 3:1 row ratio. Sarno *et al.* (1998) conducted an experiment and found that land equivalent ratio (LER) values were found to be greater in intercrop than unity. Islam *et al*. (1992) and Nargis *et al.* (2004) also got higher land equivalent ratio (LER) from intercropping practices.

Table 7: Productivity performance of mustard grown along with lentil under intercropping systems

Treatments	Relative yield of mustard	Relative yield of lentil	Combined yield (t ha^{-1})	LER
T_1	1.00	-	-	1.00
T_2	-	1.00	-	1.00
T_3	0.74	0.54	2.32	1.28
T_4	0.91	0.79	2.93	1.70
T_5	0.80	0.73	2.62	1.53
T_6	0.78	0.68	2.33	1.46
T_7	0.72	0.79	2.45	1.51
T_8	0.79	0.67	2.56	1.46
T_9	0.78	0.61	2.46	1.39
T_{10}	0.88	0.59	2.70	1.47
T_{11}	0.79	0.61	2.48	1.40
T_{12}	0.69	0.47	2.11	1.16

4.3.4 Equivalent yield

4.3.4.1 Mustard equivalent yield (MEY)

Equivalent yield of mustard was significantly affected by different intercropping systems (Table 8). The maximum mustard equivalent yield 3.56 t ha^{-1} was obtained from T_4 (One row mustard with one row lentil) treatment. The lowest mustard equivalent yield 2.48 t ha^{-1} was obtained from T_{12} (90% mustard with 10% lentil) treatment this might be due to inter and intraspecific competition between tall growing mustard with short growing lentil. Sarno *et al.* (1998) stated that higher equivalent yields were obtained with intercropping.

4.3.4.2 Lentil equivalent yield (LEY)

Equivalent yield of lentil was significantly affected by different intercropping systems (Table 8). Maximum lentil equivalent yield 1.78 t ha^{-1} was obtained from T_4 (One row mustard with one row lentil) treatment. The lowest lentil equivalent yield 1.34 t ha^{-1} was obtained from T_{12} treatment (90% mustard with 10% lentil).T_4 treatment gives highest equivalent yield might be due to one row mustard and one row lentil row arrangement was best fitted combination.

Table 8: Equivalent yield of mustard and equivalent yield of lentil as affected by intercropping systems

Treatments	Mustard equivalent yield (t ha^{-1})	Lentil equivalent yield (t ha^{-1})
T_1	2.54	-
T_2	-	.79
T_3	2.75	1.38
T_4	3.56	1.78
T_5	3.20	1.60
T_6	3.07	1.54
T_7	3.08	1.54
T_8	3.09	1.55
T_9	2.94	1.47
T_{10}	3.17	1.59
T_{11}	2.96	1.48
T_{12}	2.48	1.34

4.4 Economic performance

4.4.1 Total variable cost

Total variable cost was affected by different intercropping systems (Table 9). The highest variable cost Tk. 121578 ha^{-1} was obtained from T_5 (one row mustard with Two row lentil) treatment and the lowest Tk.49472 ha^{-1} from T_2 (Sole lentil) treatment.

4.4.2 Gross return

Gross return was affected by different intercropping systems (Table 9). The highest gross return Tk. 213600 ha^{-1} was obtained from T_4 (One row mustard with one row lentil) treatment. The lowest gross return Tk. 94800 ha^{-1} was obtained from T_2 (Sole lentil) treatment.

Chowdhury *et al.* (2009) Showed that sole pigeon pea gave the lowest gross return, net return and BCR (4.95) and sole turmeric also failed to show higher return than intercropped combination. Similar results were also found by Dakua (1992) who reported that the highest gross return was obtained in the treatment of intercropping wheat with chickpea (chickpea 5 rows + wheat 2 rows).

Singh *et al.* (1981) reported that the intercropping of wheat with chickpea, lentil or lathyrus under adequate moisture conditions, although did not give higher total grain yield and dry matter, but was economically more profitable.

4.4.3 Net return

The highest net return Tk. 103680 ha^{-1} over variable cost was obtained from T_4 (One row mustard with one row lentil) treatment (Table 9). The lowest net returns Tk. 42952 ha^{-1} was obtained from T_1 (sole mustard) treatment.

4.4.4 Monetary advantages (Tk. ha^{-1})

Monetary advantages were affected by different intercropping systems (Table 9). The highest monetary advantage value of Tk.87952.94 ha^{-1} was obtained from T_4 treatment. The second highest monetary advantage value of Tk. 66509.80 ha^{-1} was obtained from T_5 (One row mustard with two rows lentil) treatment. The third highest monetary advantage value of Tk. 62415.89 ha^{-1} was obtained from T_7 (Two rows mustard with two rows lentil) treatment. The lowest monetary advantage value Tk. 20524.14 ha^{-1} was obtained from T_{12} (90% mustard with 10% lentil) treatment.

4.5 Benefit-cost ratio

Benefit cost ratio was significantly affected by different intercropping system (Table 9). When benefit-cost ratio of each treatment was examined it was found that the treatment T_4 gave the highest benefit cost ratio (1.94). The cost and return analysis indicated that the treatment of T_4 gave the best combinations in respect of gross return, net return and benefit cost ratio.

Table 9: Economic analysis of mustard and lentil under different intercropping systems

Treatments	Total variable cost (TK. ha^{-1})	Gross return (TK. ha^{-1})	Net return (TK. ha^{-1})	Monetary advantages (TK. ha^{-1})	Benefit Cost Ratio (BCR)
T_1	70448	113400	42952	-	1.61
T_2	49472	94800	45328	-	1.91
T_3	112572	165000	52428	36093.57	1.47
T_4	109920	213600	103680	87952.94	1.94
T_5	121578	192000	70422	66509.80	1.58
T_6	115321	184200	68879	58035.62	1.60
T_7	103561	184800	81239	62415.89	1.78
T_8	109691	185400	75709	58413.69	1.69
T_9	112039	176400	64361	49493.53	1.57
T_{10}	120372	190200	69828	60812.24	1.58
T_{11}	103269	177600	74331	50742.86	1.71
T_{12}	103372	148800	45428	20524.14	1.43

Price rate: Mustard seed Tk. 60 kg^{-1} and lentil Tk.120 kg^{-1}. Variable cost includes cost of fertilizer irrigation, labor, seeds etc.

Chapter 5

SUMMARY AND CONCLUSION

An experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, during November 2017 to March 2018 to assess growth and yield variations of mustard and lentil under intercropping systems. Twelve treatment combinations were T_1 = Sole Mustard, T_2 = Sole Lentil, T_3 = 50% Mustard + 50% Lentil, T_4 = 1 Row Mustard + 1 Row Lentil, T_5 = 1 Row Mustard + 2 Rows Lentil,T_6 = 2 Rows Mustard + 1 Row Lentil, T_7 = 2 Rows Mustard + 2 Rows Lentil,T_8 = 3 Rows Mustard + 1 Row Lentil, T_9 = 3 Rows Mustard + 2 Rows Lentil, T_{10} = 70% Mustard + 30% Lentil, T_{11} = 80% Mustard + 20% Lentil, T_{12} = 90% Mustard + 10% Lentil. The experiment was conducted in Randomized Complete Block design with three replications. The experimental materials were Mustard (BARI Sharisha-16) and Lentil (BARI Masur-7). Seeds of these crops were sown on 1 November 2017 and harvested on 31 january 2018. Growth, yield, productivity and economic performance were studied. The data were analyzed statistically and means were compared by least significant difference (LSD) method.

The results of the experiment revealed that some of the crop characteristics and yield of mustard and lentil were significant due to intercropping systems. At maturity, the highest plant height (92.65 cm) of mustard was obtained from T_4 treatment and the lowest (85.43 cm) was obtained from T_1 treatment. Branch number of mustard at harvest was affected significantly by different intercropping systems. Number of silique plant^{-1}, number of seeds siliquae^{-1} and 1000 grain weight of mustard were also affected significantly by different intercropping systems. The highest number of silique plant^{-1}(160) was obtained from T_1 treatment and the lowest (108.3) was obtained from T_{12} treatment. The highest number of seeds silique (21.77) was obtained from T_3 treatment and lowest (19.87) was obtained from T_8 treatment.

Mustard seed yield was affected significantly by different intercropping systems. The highest seed yield (2.54 t ha^{-1}) obtained from T_1 treatment (Sole mustard). Among the intercropping system the highest yield (2.30 t ha^{-1}) obtained from T_4 treatment. On the contrary, the lowest yield (1.74 t ha^{-1}) was obtained from T_{12} treatment, which may be due to applying broadcasting method. Plant height, number of branches plant^{-1}, dry weight, number of pods plant^{-1} and 1000 seed weight of lentil were also affected significantly by different intercropping systems.

The yield of lentil also affected significantly by different intercropping systems. The highest seed yield of lentil (0.79 t ha^{-1}) obtained from T_1 treatment (Sole lentil). The lowest seed yield of lentil (0.37 t ha^{-1}) was obtained from T_{12} treatment. This might be due to presence of inter competition with mustard which was broadcasted with lentil.

Harvest index of mustard lentil were also affected significantly by different intercropping systems. Maximum harvest index of mustard (24.45%) was obtained from T_8 treatment and the lowest (19.41%) was obtained from T_{12} treatment. Maximum harvest index of lentil (52.85 %) was obtained from T_2 treatment and the lowest (40.13%) was obtained from T_9 treatment.

Relative yield of mustard and lentil were found to be significantly higher in intercrop treatments than those of their respective sole crops. Land equivalent ratio was also affected by different intercropping systems. The highest land equivalent ratio of 1.90 was obtained from T_4 treatment and the lowest 1.16 was obtained from T_{12} treatment. The highest mustard equivalent yield of 3.56 t ha^{-1} was obtained from T_4 treatment and the highest lentil equivalent yield of 1.78 t ha^{-1} was obtained from T_4 treatment.

On the contrary, the lowest mustard equivalent yield of 2.48 t ha^{-1} was obtained from T_{12} treatment. The lowest lentil equivalent yield of 0.79 t $ha^{-1}$was was obtained from T_2 treatment.

The highest monetary advantage of Tk. 87952.94 ha^{-1} was obtained from T_4 treatment and the lowest Tk. 20524.14 ha^{-1} was obtained from T_{12} treatment.

The highest combined yield 2.93 t ha^{-1} was obtained from T_4 treatment and the lowest combined yield 2.11 t $ha^{-1}$was obtained from T_{12} treatment.

The highest gross return of Tk. 213600 ha^{-1} and net return Tk. 103680 ha^{-1} was obtained from T_4 treatment. The highest benefit cost ratio of 1.94 was obtained from T_4 treatment. The lowest benefit cost ratio of 1.43 was obtained from T_{12}.

The results revealed that was seen T_4 treatment gave highest LER, gross return, net return, equivalent yield, benefit cost ratio and monetary advantages among the treatments.

It may be concluded that the planting pattern of one row mustard with one row lentil of intercropping system is potential management to evaluate their production for nutritional security under cost effective experimental procedure.

Chapter 6

REFERENCES

Afzal, M. A., Bakr M. A. and Rahman M. L. (1999). Lentil Improvement in Bangladesh, Asia-Pacific Association of Agricultural Research Institutions, pp1- 36.

Agboola, A. A. and Fayemi, A. A. (1971). Preliminary trials on the intercropping of maize with different tropical legumes in western Nigeria. *J. Agr. Sci.* **77**: 219-225.

Agrikar G. P. (1979). Grain in pulse crops of India Paper Presented in the in the International Workshop on Grain Legumes. January: 13-16, 1975. ICRISAT, p. 46.

Ahmad, S. and Rao, M.R. (1982). Performance of maize-soybean intercrop combination in the tropics: Results of a multilocation study. *Field Crops Res.,* **5**: 147-161.

Akanda, M. E. and Quayyam, M. A. (1982). Effect of intercropping soybean, cowpea, mungbean , blackgram and groundnut with maize. *Bangladesh J. Agric. Res* . **7**(2): 66-69.

Akter, M. D. N., Alim, A., Islam, M.M., Naher, Z., Rahman, M. and Hossain, A. (2004). Evaluation of mixed and intercropping of lentil and wheat. *Agron. J.* **3**: 48-51.

Allen, J. R. and Obura, R.K. (1983). Yield of corn, cowpea and soybean under different intercropping system. *Agron. J.* **75**:1005-1009.

Andrews, D. J. (1972). Intercropping with guineacorn – a biological cooperative. *Shanura Agric. Newsl.* **14**(2): 20 - 22.

Andrews, D. J. and Kassam, A. H. (1976). The importance of multiple cropping in increasing world food supplies. In: Multiple Cropping, American Soc. Agron, Special publication. No.37 pp.1-10.

Anjaneynlu, V. R., Singh, S. P. and Pal, M. (1982). Effect of competion free period and technique and pattern of pearl millet planting on growth and yield of Mungbean and total productivity in sole pearl millet and pearlmillet-mungbean intercropping system. *Indian Agron. J.* **27**(3): 55-58.

Anil L., Park J., Phipps R. H. and Miller F. A. (1998). Temperate intercropping of cereals for forage: A review of the potential for growth and utilization with particular reference to the UK. *Grass forage Sci*. **53**: 301-317.

Awal, M. A., Koshi, H. and Lkeda,T.(2006). Radiation interception and use by maize/peanut intercrop canopy. *Agric. For. Meteorol*.,**139**:74-83.

Bandopadhyay, S. K. (1984a). Nitrogen and water relations in grain sorghum legume. *Bangladesh J. Agric. Res*. **6**(2): 27-31.

Bandyopadhyay, S. K. (1984b). Nitrogen and water relation in grain sorghum-legume intercropping systems. Ph.D. Thesis, IRRI, New Delhi-12, India.

Barker, C. M. and Blamey, F. P. (1985). Nitrogen fertilizer effects on yield and nitrogen uptake of sorghum and soybean growth in sole and intercropping systems. *Field Crops Res.,* **12**: 233-240.

Bautista, B. R. (1988). The production of grains and stocks by maize as affected by intercropping with legumes. *Philipp. Agric.* **7**(2): 36 – 46.

Banik, P., Midya A., Sarkar B. K. and Ghose S. S. (2006). Wheat and chickpea intercropping systems in on additive experiment: Advantages and weed smothering. *European J. of Agron*. **24**: 325-332.

Bangladesh Bank. (2012). Monthly Economic Trends, Statistics Department, Bangladesh Bank, Dhaka, Bangladesh.

BBS. (2015). Bangladesh Bureau of Statistics, Statistical Yearbook of Bangladesh, Statistics Division, Ministry of planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS. (2016). Bangladesh Bureau of Statistics, Statistical Yearbook of Bangladesh, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

Bray, R. H. (1954). A nutrient mobility concept of soilplant relationships. *Soil Sci.* **78**: 9-22.

Chetty, C. R. K. and Reddy, M.N. (1984). Analysis of intercrop experiments in dry lands Agriculture. *Expt. Agric.* **20**: 31-40.

Chowdhury, J. A., Ahmed, A. U., Mondal, A. T. M. A. I. and Kuhinur, S. (2009). Study on the intercropping turmeric (*Curcuma longa*) with pigeonpea (*Cajganas cajan*) at different row combinations. *Bangladesh J. Agri.* **34**(1): 19-23.

Dalrymple, D. (1971). Survey of multiple cropping in less developed nations. USDA, Washington. pp. 50 - 52

Dakua, S. K. (1992). Performance of chickpea and wheat under mixed and intercropping at variable seeding ratios. M.S. Thesis, Department of Agronomy. BAU. Mymensingh, Bangladesh.

Das K. R., Sarker, J. R. and Akhter, S. (2016). Measurement of Inconsistency between Area and Production of Pulse in Bangladesh. *Inter. J. Stat. and Applications,* **6**(3): 89- 95.

Dwivedi, D. K., Sah, A. K., Jagdish, D., Thakur, S. S., Singh, S. J., Pandey, I. B. and Dubey, J. (1998). Intercropping practice with irrigated wheat. *J. Res. Birsa Agric. Univ*. **10**(2): 183-184.

Elias, S. M., Hossain, M. S., Sikder F. S., Ahmed, J. and Karim M. R. (1986). Identification of Constraints to Pulse Production with Special Reference to Present Farming Systems, Annual Report of the Agricultural Economics Division.

Fisher, N. M. (1977). Studies in mixed cropping –seasonal differences in relative productivity of crop mixture and pure stands in the Kenya lands. *Expt. Agric.* **13**:177-184.

Fininsa, C. (1997). Effect of planting pattern, relative planting data and intra-row spacing on aharicot bean/ maize intercrop. *African Crop Sci. J*. **5**: 15-22.

Fukai, S. and Trenbath, B. R (1993) Processes determining intercrop productivity and yields of component crops. *Field Crop Res* **34:** 247-271.

Ghaley B. B., Hauggaard-Nielsen H., Hogh-Jensen H. and Jensen E. S. (2005). Intercropping of wheat and pea as influenced by nitrogen fertilization. *Nutr. Cycl. Agroecosyst*. **73**: 201–212.

Hashem, A. (1983). Effect of intercropping maize and cowpea at varying plant population levels. M. Sc. (Ag.) Thesis, Dept. Agron. BAU, Mymensingh.

Hauggaard-Nielsen, H. and Jensen, E. S (2001). Evaluating pea and barley cultivars for complementarity in intercropping at different levels of soil N availability. *Field Crops Res*. **72**: 185-196.

Hamjah, M. A. (2014). Climatic effects on major oilseed crops production in Bangladesh: an application of multiple regression model. J. of Eco. and Sust. Dev., **5**(19): 45-59.

Hossain, M. A. and Bari, A. K. M. A. (1996). Effect of intercropping groundnut with garlic at varying plant population levels. *Bangladesh Hort*. **24**:29-43.

IRRI (International Rice Research Institute) (1973). Multiple cropping, In: IRRI Annual Report for 1973. Losbanos, Philippines, **pp**. 15-35.

Islam, K. M. M., Samad, M. A., Sarkar, M. A. R., Khan, M. N. H. And Rahman, M. L. (1992). Effect of itercropping of spices and pulse crop with winter jute seed. *Bangladesh Jute Fib. Res*. **17**(1): 6-9.

Jensen, E. S. (1996). Grain yield and symbiotic N_2 fixation and interspecific competition for inorganic N in pea-barley intercrops. *Plant and Soil*, **182**: 25-38.

Kalra, G. S. and Ganger, B. (1980). Economics of intercropping of different legumes with maize at diffrernt levels of N under rainfed conditions. *Ind. J. Agron.* **25**: 181-185.

Khushu, M. K. (2001). Performance of lentil (*Lens culinaris*) and toric (*Brassica compestris*) intercropping with wheat (*Triticum aestivum*) under rainfed conditions of north-west Himalaya. *Cruciferae Newsl.* **23**: 65–66.

Krantz, B. A., Birmani, S. M., Singh, S. and Rao, M. R. (1976). A report presented at the Symposium on Intercropping in the Semi-arid Areas at Morogoro. Tanzania, May 11, 1976. p. 23.

Li, L., Sun, J., Zhang, F., Li, X., Yang, S. and Rengel, Z. (2001). Wheat/maize or wheat/soybean strip intercropping, yield advantage and interspecific interaction on nutrients. *Field Crop Res*., **71**: 123-137.

Markunder, S. K., Dahatonde, B. N., yadav, S. and Gangrarde, S. K. (1997) lntercroping of wheat with lentil for higher monetary returns. *Indian J. Agril.. Sci*. **55**(5):332.

Malik, M. A., Hayat, M. A., Ahmad, S., Haq, L. and Ahmad, S. (1998). Intercropping of lentil, gram and rape in wheat under rainfed conditions. *Sarhad J. Agric.* **14**(5): 417- 42 1.

Mashingaidze, A. B. (2004). Improving weed management and crop productivity in maize systems in Zimbabwe. Ph.D Thesis. Wageningen University, Wageningen, The Netherlands.

Mallik M. S. A. (2013). Quality seed production of oilseed crops, *Bangladesh Agric. Res. Ins.*

Mead, R. and Willey, R. W. (1980). The concept of land equivalent ratio and advantages in yields from intercropping. *Expt*. *Agric.* **16**(3): 217-228.

Midmore, D. J. (1993) Agronomic modification of resource use and intercrop productivity. *Field Crop Res* 34: 357-380.

Miah M. A. M., Rashid M. A. (2015). Profitability and Comparative Advantage of Oilseed Production in Bangladesh. Bangladesh Development Studies, **38**(3):35-54.

Moody, K. and Shetty, S. V. R. (1979). Weed management in intercropping systems. In: proceedings of the International Workshop on intercropping, ICRISAT, Hyderabad, India, 10-13 Jan. 1979. **pp**.229-237.

Moris, R. A., and D. P. Garrity, (1993). Resource capture and utilization in intercropping: water. *Field Crops Research* **34**:303-317.

Mugabe, N. R., Sinje, M. E and Sibuga, K. P. (1982). A Study of Crop Weed Competition in Intercropping. In: Intercropping in Semi Arid Areas, Keswani, C.L. and B.J. Ndunguru (Eds.). National Scientific Research Council and International Development Research Center, Tanzania, **pp**: 96-101.

Nargis, A., Alim, M. A., Islam, M. M., Zabun, N., Maksuder, R. and Hossain, A. S. M. I. (2004). Evaluation of mixed cropping and Intercropping of lentil and wheat. *Bangladesh Jute Res. Ins. J.* **3**(1): 48 - 51.

Nazir. M. S., Elahi. B., Jabbar. A., Saced, M. and Ahmad, R. (1997). Bio-economic assessment of different wheat based intercropping systems. *Pakistan. J. Agric*. **34**(1 - 4): 62 - 64.

Ofori, F. and Stern, W. R. (1987). Cereal-Legume intercropping systems. *In: Adv. Agron.* **41**: 41-90.

Oleksy, A. and Szmigiel, A. (2002). Formation of selected morphological features of winter triticale depending on its share in a mixture with wheat. Folia Univ. Agric., Poland. **91**: 101 – 106.

Pathic.D. S. and Malla, M. L. (1979). Study on the performance of corn-legumes under monoculture and intercrop combination. 6th Annual Maize development workshop, Nepal.

Palaniappan, R. P. (1988). Cropping system in the tropics, principal and management. Willely Eastern Ltd. New Delhi, India. p.26.

Patra, A. P. (1994). A study of root and shoot interactions between cereals and peas in mixtures. *Environ. Ecol.* **12**: 827–831.

Pandita, A. K., Shah, M. H. and Bali, A. S. (1998). Row ratio in maize (*Zea mays*) legume intercropping in temperate vally condition. *Indian J. Agric. Sci.* **68**: 633-635.

Potdar, M. V., Anders M. M., and Sharma M. M. (1994). Yield advantages and economic returns from pigeonpea/cotton strip intercropping rotations on a vertisol in the Indian semi-arid tropics. Submitted to International Workshop on Dynamics of Roots and Nitrogen in Cropping Systems of the Semi-Arid Tropics. 21-25 Nov. Hyderabad, India, pp502- 234.

Rao, M. R., and Willey, R. W. (1980). Evaluation of yield stability in intercropping studies On sorghum/pigeonpea. *Expt Agric*, **16** : 105-106.

Rao, M. R. and M. Singh. (1990). Productivity and risk evaluation in constrasting intercropping systems. Field Crop Res.**23**: 279.

Razzaque, M. A. (1980). New research information on wheat. Workshop on Modern rice cultivation in Bangladesh. February 25 - 27. BRRI, Joydebpur Gazipur. **pp**. 41 - 47.

Rathore, A. L. (1998). Physiological basis for yield advantage in a sorghum/groundnut intercrop exposed to drought. Dry-matter production, yield and light interception. *J. Sci. Food Agric*. **78**: 149–161.

Rahman, M. S., Hossain, M. A., Sarker, M. J. U. and Bakr, M. A. (2012). Adoption and profitability of Bari lentil varieties in some selected areas of Bangladesh. *Bangladesh J. Agric. Res.,* **37**(4): 593-606.

Sarno, I.C., iristina. L. Carrubba. A. and Trapani. P. (1998). l)urum wheat - fieldpea intercropping in semi - arid mediterranean environments. *Agron. Geut. Sd.* **32**(I): 62 - 7 I.

Senanayake L., Knievel D. P. and Stevena S. E. (1987). Nodulation and symbiotic nitrogen fixation of cowpea. *Plant Soil,* **99**:435-439.

Seran, T. H. and I. Brintha, (2009). Study on biological and economic efficiency of Radish (*Raphanus sativus* L.) intercropped with vegetable amaranthus (*Amaranthus tricolor* L.). *Open Hortic. J.,* **2**: 17-21.

Seran, T. H., and Brintha, I. (2010). Review on maize based intercropping. *J. Agron*, **9** (3): 135-145.

Saxena, M. C. (1972). Concept of paralled multiple cropping. *J. Agric. Sci. Camb.* **77**: 219-225.

Shackel, K. A. and Hall, A. E. (1984). Effect of intercropping on the water relations of sorghum and cowpea. *Field Crops Res*. 8: 381-387.

Sharma, K. C., Sing,Y., Gupta, P. C., Tripathy, S. K., Bhardwaj, A. K. and Singh, S. P. (1986). Plant population and spatial arrangement in wheat-mustard intercropping. *Indian J. Agron*.31: 154-157.

Singh, S. P. (1981). Intercropping studies in India. Proceedings of the international workshop on intercropping. Hyderabad, India. **pp**. 22-24.

Singh, N. B., P. P. Singh and Nair, K. P. P.,(1996). Effect of legume intercropping on enrichment of soil nitrogen , bacterial activity and productivity of associated maize crops. *Exp. Agric*., **22**: 339-344.

Singh, O. B. (1999). Yield and economics as influenced by intercrops of maize *(Zea mays),* groundnut (*Arachis hypogaea*) and greengram (*Phaseolus radiatus*). *Indian J. Pulses Res*. **12**: 260–262.

Singh, L. (2009). Yield advantage, reciprocity functions and energy budgeting of lentil (*Lens culinaris*) + oat (*Avena sativa*) intercropping under varying row ratio and phosphorus management. *Indian J. Agron.* **54**: 291–295.

Srivastava R. K., Bohra, J. S, and Singh R. K, (2007). Yield advantage and reciprocity functions of wheat (*Triticum aestivum*) + Indian mustard (*Brassica juncea*) inter-cropping under varying row ratio, variety and fertility level. *Ind. J. Agric. Sci.* **77**(3):139-44.

Tiwari, K. P. (1992). Performance of lentil (*Lens culinaris*) and toric (*Brassica compestris*) intercropping with wheat (*Triticum aestivum*) under rainfed conditions . *J. Oilseeds Res.* **9**: 248–252.

Trenbath, B. R. (1974). Biomass productivity of mixtures. *Adv. Agron*. **20**: 177-210.

Trenbath, B. R. (1976). Plant interactions in mixed communities. In 'multiple cropping' (R.I. Papendick, P.A. Sanchez, and G.B. Triblett eds.) **pp**. 129-170 Amor. Soc. Agron. spec. pub. No. 27, Madison, Wiscosin. Gurigbal, S. (2010). The soybean: Botany, Production and Uses. Ludhiana, India: Cabi Publishers.

Trenbath, B. R. (1993). Intercropping for the management of pests and diseases. *Field Crops Res.,* **34**: 381-405.

Tsubo, M., Walker, S. and Mukhala, E. (2001) Comparisons of radiation use efficiency of mono-/inter-cropping systems with different row orientations. *Field Crops Res.* **71**:17-29.

Uddin M. S. and Sattar. M. A. (1993). Prospects of intercropping maize with legumes and vegetables in Hill tracts. *Bangladesh J. Agril. Res*. **18**: 227-230.

Verma, U. N., Thakur, R.., Pal, S. K. and Singh, M. K. (2008). Fertilizer management in wheat (*Triticum aestivum*) + lentil (*Lens culinaris*) intercropping system. *J. Res. Birsa Agric. Univ*. **9**(1): 39 - 41.

Waghmare, A. B., Krishnan, T. K. and Singh, S. P. (2005). Crop compatibility and spatial arrangement in sorghum based intercropping systems. *J. Agril. Sci. Cambridge*. **38**: 99.

Wahua, T. A. T. (1983). Nutrient uptake by intercropped maize and cowpeas and a concept of nutrient supplementation index (NSI). *Exp. Agric*. **19**: 263- 275.

Willey, R. W. (1979). Intercropping: Its importance and research needs, Part II. Agron. Res. approach. *Field crop abst*. **32**: 73 - 78.

Willey, R. W. and M. S. Reddy, (1981). A field technique for seperating above and below ground interaction for intercropping of expt with pearl millet/groundnut. *Exp*. *Agric*., **17**: 257-264.

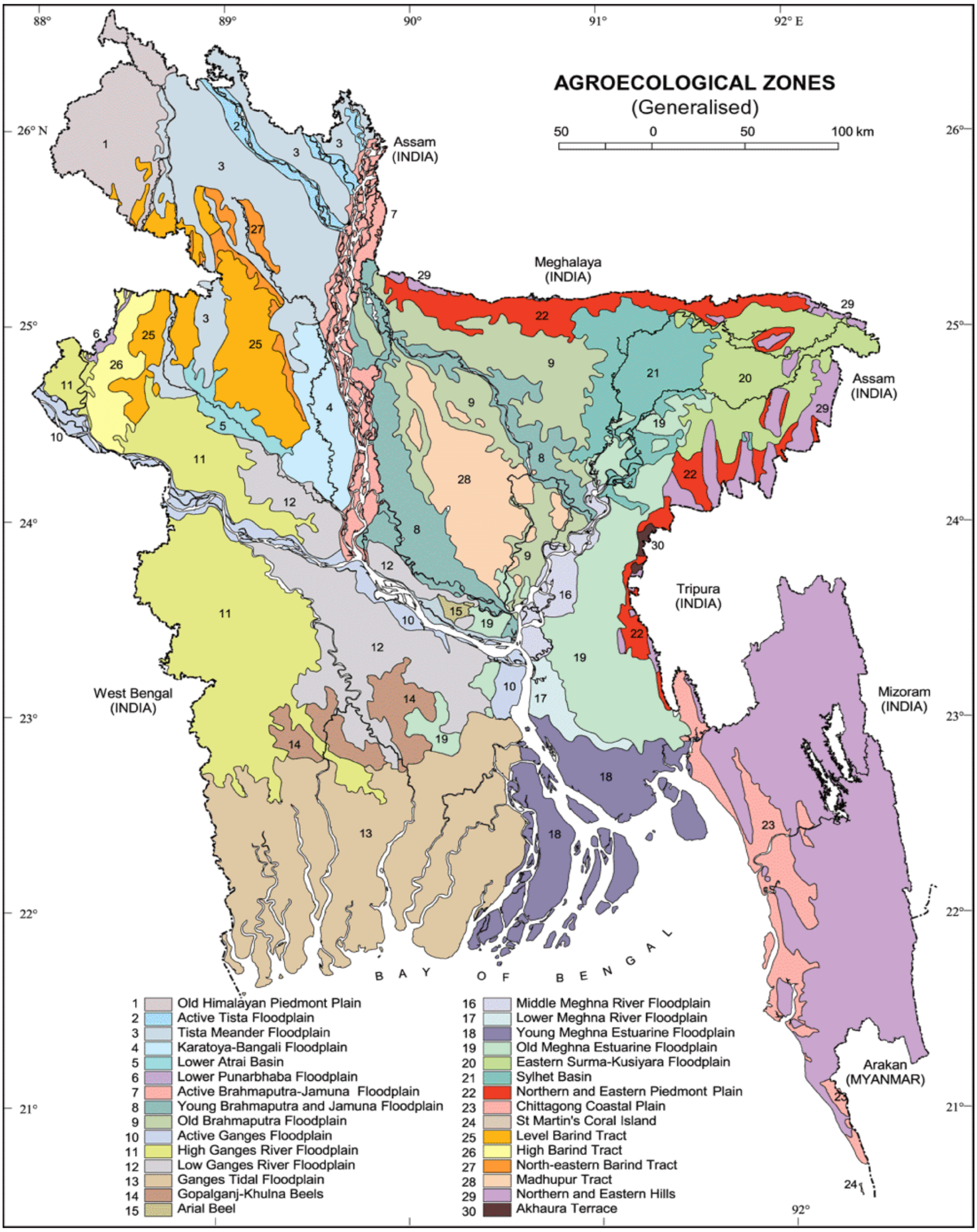
Willey, R. W. (1985). Evaluation and presentation of intercropping advantages. *Expt*. *Agric.* **21**: 119-133.

Woolley, J. and Davis, J. H. C. (1991). The Agronomy of Intercropping with Beans. In: Common Beans: Research for Crop Improvement, Van Schoonhoven, A. and O. Voyeset (Eds.). CAB International in Association with CIAT, Wallingford, **pp**: 707-735.

Zandstra, G. H. (1979). Terminologies in cropping systems "Definitions and Parameters", lecture notes of six month cropping systems training program IRRI.

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Monthly average air temperature, relative humidity and total rainfall of the experimental site during 2017-2018

Month	Air temperature		Relative humidity (%)	Total rainfall (mm)
	maximum	minimum		
November	29.88	14.56	70.23	00
December	26.75	14.25	69.67	00
January	25.00	13.11	68.31	00
February	30.11	17.59	52.19	00

Source: Bangladesh Mateorological Department (climate and weather division), Agargaon, Dhaka

Appendix III. ANOVA on plant height of mustard as influenced by inter cropping with lentil

Source of variation	df	Mean square values of plant height of mustard at different days after sowing				
		20	40	60	80	At harvest
Replication	2	5.79	66.77	157.47	21.49	115.04
Treatment	10	1.96*	76.77*	74.98^{NS}	11.21^{NS}	10.21^{NS}
Error	20	1.47	32.89	76.21	108.20	84.91

*Significant at % 5 level of significance

^{NS} Non significant

Appendix IV. ANOVA on above ground dry matter of mustard as influenced by inter cropping with lentil

Source of variation	df	Mean square values of above ground dry matter of mustard at different days after sowing				
		20	40	60	80	At harvest
Replication	2	0.00	0.03	4.64	0.22	0.22
Treatment	10	0.001*	0.05*	3.62*	0.78^{NS}	0.78^{NS}
Error	20	0.00	0.07	0.46	0.72	0.72

*Significant at % 5 level of significance

^{NS} Non significant

Appendix V. ANOVA on branch number of mustard as influenced by inter cropping with lentil

Source of variation	df	Mean square values of branch number of mustard at different days after sowing			
		40	60	80	At harvest
Replication	2	0.53	0.23	0.65	0.36
Treatment	10	1.45*	1.88*	0.90*	0.81*
Error	20	0.13	0.99	0.86	0.97

*Significant at % 5 level of significance

Appendix VI. ANOVA on number of siliqua plant^{-1},seeds silique^{-1} 1000 seed weight, seed yield and harvest index of mustard as influenced by inter cropping with lentil

Source of variation	df	Mean square				
		Siliqua plant^{-1}	Seeds silique^{-1}	1000 seed weiight	Seed yield	Harvest index
Replication	2	46.03	1.26	0.007	0.047	2.41
Treatment	10	884.29*	0.79*	0.02^{NS}	0.16	8.19*
Error	20	208.76	4.53	0.08	0.05	5.89

*Significant at % 5 level of significance

^{NS} Non significant

Appendix VII. ANOVA on plant height of lentil as influenced by inter cropping with mustard

Source of variation	df	Mean square values of plant height of lentil at different days after sowing					
		20	40	60	80	100	At harvest
Replication	2	1.18	1.31	0.39	2.95	6.55	3.56
Treatment	10	2.06*	7.78*	26.56*	3.20^{NS}	6.41^{NS}	14.99^{NS}
Error	20	0.81	4.72	15.42	12.50	14.54	18.03

*Significant at % 5 level of significance

^{NS} Non significant

Appendix VIII. ANOVA on above ground dry matter of lentil as influenced by inter cropping with mustard

Source of variation	df	Mean square values of above ground dry matter of lentil at different days after sowing					
		20	40	60	80	100	At harvest
Replication	2	0.00	0.00	0.002	0.03	0.07	0.015
Treatment	10	0.00^{NS}	0.00*	0.006*	0.01^{NS}	0.24*	0.018^{NS}
Error	20	0.00	0.00	0.001	0.02	0.12	0.116

*Significant at % 5 level of significance

^{NS} Non significant

Appendix IX. ANOVA on branch number of lentil as influenced by inter cropping with mustard

Source of variation	df	Mean square values of branch number of lentil at different days after sowing				
		40	60	80	100	At harvest
Replication	2	0.002	1.14	0.76	3.49	4.26
Treatment	10	1.173*	1.30*	1.72*	4.23*	4.42*
Error	20	0.200	0.70	1.60	2.64	3.59

*Significant at % 5 level of significance

Appendix X. ANOVA on number of pods plant^{-1},seeds pod^{-1}, 1000 seed weight, seed yield and harvest index of lentil of lentil as influenced by inter cropping with mustard

Source of variation	df	Mean square				
		Pods plant^{-1}	Seeds pod^{-1}	1000 seed weight	Seed yield	Harvest index
Replication	2	124.04	0.001	1.55	0.002	3.03
Treatment	10	1105.03*	0.023*	2.09^{NS}	0.41*	43.15*
Error	20	40.52	0.034	4.19	0.003	18.39

*Significant at % 5 level of significance

^{NS} Non significant

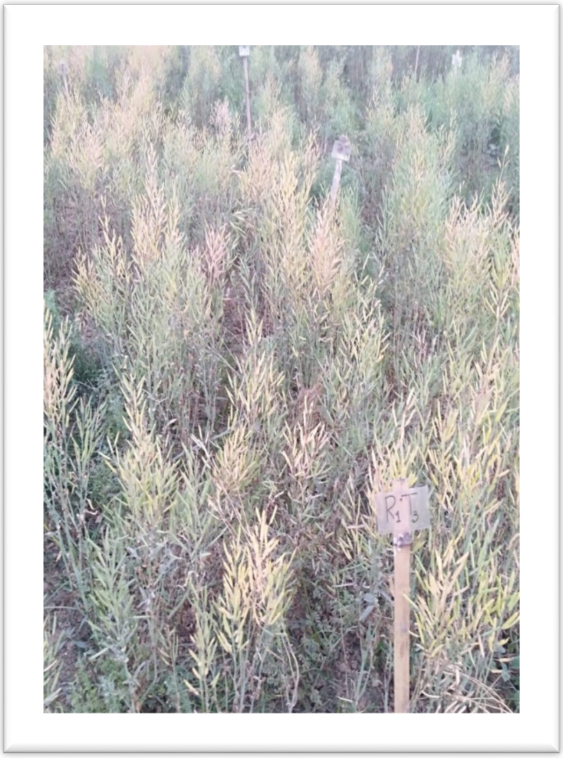


Plate 1: 50% Mustard with 50% lentil

Plate 2: One row mustard with one row lentil

Plate 3: One row mustard with two row lentil

Plate 4: 90% mustard with 10% lentil