INTERCROPPING OF WHEAT PAIRED ROW WITH GRASSPEA AND LENTIL UNDER DIFFERENT LEVELS OF NITROGEN

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CERTIFICATE

This is to certify that the thesis entitled, "*INTERCROPPING OF WHEAT PAIRED ROW WITH GRASSPEA AND LENTIL UNDER DIFFERENT LEVELS OF NITROGEN*" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in AGRONOMY, embodies the result of a piece of *bona fide* research work carried out by MOHAMMAD SHAHIDUL ISLAM, Registration No. 08-03241 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
Place: Dhaka, Bangladesh

Prof. Dr. Md. Fazlul Karim
Supervisor

Dedicated to
My
Beloved Parents

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ACRONYMS

AEZ	=	Agro- Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BARI	=	Bangladesh Agricultural Research Institute
BCR	=	Benefit Cost Ratio
cm	=	Centi-meter
cv.	=	Cultivar (s)
CV (%)	=	Percentage of Coefficient of Variance
^0C	=	Degree Centigrade
DAS	=	Days After Sowing
et al.	=	And others
etc.	=	Etcetera
FAO	=	Food and Agriculture Organization
g	=	gram (s)
ha	=	hectare
HI	=	Harvest Index
Hr	=	hour (s)
kg	=	Kilogram
LER	=	Land Equivalent Ratio
LSD	=	Least Significant Difference
m	=	meter
mm	=	millimeter
MoP	=	Muriate of Potash
m^2	=	Square meter
N	=	Nitrogen
No.	=	Number
NR	=	Normal Row
NS	=	Not significant
PR	=	Paired Row
SAU	=	Sher-e-Bangla Agricultural University
t ha^{-1}	=	Tons per hectare
TSP	=	Tripple Super Phosphate
UNDP	=	United Nations Development Program
var.	=	Variety
WPR	=	Wheat Paired Row
%	=	Percentage

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ABSTRACT

An experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, during November 2009 to March 2010 to assess the intercropping system of wheat with grasspea and lentil under different spatial arrangement and nitrogen level. Fourteen treatment combinations were T_1 = Wheat normal row + 100kg N ha^{-1}, T_2 = Wheat paired row (WPR) + 100kg N ha^{-1}, T_3 = Sole grasspea + 20kg N ha^{-1}, T_4 = Sole lentil + 20kg N ha^{-1}, T_5 = WPR + 1 row grasspea + 80kg N ha^{-1}, T_6 = WPR + 1 row grasspea + 100kg N ha^{-1}, T_7 = WPR + 1 rows grasspea + 120kg N ha^{-1}, T_8 = WPR + 1 row lentil + 80kg N ha^{-1} T_9 = WPR + 1 row lentil + 100kg N ha^{-1}, T_{10} = WPR + 1 row lentil + 120kg N ha^{-1}, T_{11} = Wheat + lentil (3:1) + 80kg N ha^{-1} , T_{12} = Wheat + lentil (3:1) + 100kg N ha^{-1} T_{13}= Wheat + lentil (3:1) + 120kg N ha^{-1} ,T_{14}= Wheat + grasspea (3:1) +100kg N ha^{-1}.The experiment was conducted in Randomized Complete Block design with three replications. The experimental materials were wheat (cv. shourav), grasspea (cv. BARI khesari-2) and lentil (cv. BARI moshur-4). Seeds of these crops were sown on 16 November 2009 and harvested on 10 March 2010. Growth, yield, productivity and economic performance were studied. Results revealed that, intercropping system significant by effect on plant height, tillers $plant^{-1}$, above ground dry matter $plant^{-1}$, length of spike, spikelet $spike^{-1}$, 1000 grain weight, grain yield and harvest index of wheat. 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 grasspea and lentil. Intercropping reduced the sole wheat yield but economic analysis showed highest gross return (Tk. 88890 ha^{-1}), net return (Tk. 40047 ha^{-1}), and monetary advantage (Tk.16621.70 ha^{-1}) were obtained from T_6 (WPR + 1 row grasspea + 100kg N ha^{-1}) which was an agronomic advantage compensating the yield losses in wheat under intercropping system. The higher economic values eventually determined the maximum benefit-cost ratio (1.82) compared with BCR (1.57) for wheat normal planting. In this intercropping system, grasspea showed better compatibility than lentil when intercropped with wheat.

Chapter 1
INTRODUCTION

Intercropping is the system where two or more crops grown simultaneously in the same land at the same time. Crop production can be intensified through intercropping (Zandstra, 1979). In the tropical and sub-tropical regions, cereal-legumes intercropping are the most popular practices because of its many additional advantages (Okigbo and Greenland, 1979). Intercropping is not only a means of augmentation of crop production and monetary returns over space and time but also provides insurance against total crop failure and / or provides better avenues of employment for the rural folk (Bandyopadhyay, 1984). Though cereal-legumes intercropping have many advantages but all crop combinations are not equally profitable (Mandal and Mahapatra, 1990; Shah *et al.* 1991).

Wheat (*Triticum aestivum* L.) is the first on cereal crop of the world, occupying 17% (one sixth) of crop acreage worldwide, feeding about 40% (nearly half) of the world population and providing 20% (one fifth) of total food calories and protein in human nutrition (Gupta *et al*., 2008).

Only rice cannot fulfil the cereal demand. Wheat is the second important cereal crop in Bangladesh. Therefore, efforts are being made to increase the production of wheat. The total land acreage of wheat in Bangladesh was 0.39 million ha and the total production was 0.84 million metric tones with an average yield of 2.15 t ha^{-1} in 2007-08 (BBS, 2008).

Wheat seed contains plenty of proteins (12.6%), vitamins and minerals. As a second cereal crop, its importance is high in Bangladesh and increasing day by day. In Bangladesh, wheat is grown in upland condition during the rainfed season (November- March). The monthly maximum and minimum temperature during this period ranges from 25.8 to 30.5°C and 13.8 to 20.3°C in the south east zone and from 24.9 to 32.3°C and 10.3 to 16.7°C in the north east zone respectively (Hossain *et al*., 2001).

In Bangladesh, various types of pulses are grown. Among them grasspea, lentil, mungbean, blackgram, fieldpea and chickpea are important. Only grasspea, lentil, blackgram and chickpea contribute more than 75% of the total production of pulses.

According to FAO (1999) recommendation a minimum intake of pulse should be 80 g $day^{-1}head^{-1}$. In Bangladesh it is approximately 12 g day^{-1}. This is because that our national production of pulses is not adequate to meet up our demand.

The pulse production is decreasing or it is being neglected due to increasing cultivation of boro rice, wheat and maize. The presence of these crops, pulses are cultivating one marginal land these finally lower yield.

Grasspea (*Lathyrus sativus*) is popularly known as khesari, chickling pea, Indian vetch etc. The grasspea consumed as pulse and can be used in dhal preparation and bread making. It can be used in making local beverage. Leaves can be used as a pot-herb and can be consumed as vegetable after boiling. Seeds are dehusked and parched before use (Kay, 1979).

Germination of grasspea seeds enhances content of vitamins, especially folic acid, biotin and pyridoxine. The seeds contain 1.5% sucrose, 6.8% pentanose, 3.6% phytin, 1.5% lignin, 6.69%albumin, 13.3% globulin and 3.8% glutenin (Duke, 1981).

The total land acreage of grasspea in Bangladesh was 15.92 thousand ha and the total production was 13.42 thousand metric tones with an average yield of 1.19 t ha^{-1} in 2003-2004 (BBS, 2005).

Lentil (*Lens culinaris* Medik) is the most important pulse in Bangladesh. Lentil is an excellent source of vitamin A, vitamin B, potassium, iron and provides fiber. Its protein content ranges from 22 to 35%. It is an excellent supplement to cereal grain diet because of its good protein / carbohydrate content. It is used in soups, stews, casseroles and salad dishes. Lentil can be used as green manure crop and Indian head variety provides a large amount of fixed nitrogen estimated to be 20 lb/acre (Oplinger *et al.,* 1990). However, lentils must be teamed with a grain, such as rice, pasta or barley, to compete and enhance their protein availability to the body. Unlike meat, poultry, fish and eggs, the protein of lentil contains no cholesterol and virtually no fat.

The total acreage of lentil in Bangladesh was 68.83 thousand ha and the total production was 72 thousand metric tones with an average yield of 0.96 t ha^{-1} (BBS, 2008).

Instead of uniform row, paired row planting of cereal is an advantageous management which ultimately improves the gross return by fitting legume crops between the wider spaces of paired cereal crop. Singh (1979) observed that sorghum gave maximum yield and monetary advantage when grown between paired rows of maize. He reported that component crops being grown in wider spaces of paired row system enable the plants to utilize efficiently the soil nutrients and solar radiation. Karim *et al.* (1990) reported that the monetary advantage from groundnut cultivation between paired rows of maize.

In recent studies scientist suggested that pulse can be fitted in between two wheat paired rows these improving cropping intensity. Thus it is very urgent to improve pulse yield with high yielding variety cultivating on the main land. The only way is to bring back pulse on the main land through intercropping pulse with cereal crop. From the above reality, the experiment was initiated with following objectives:

i) To study the total yield of wheat + grasspea / lentil under intercropping systems.

ii) To determine the wheat + grasspea / lentil intercropping system under different spatial arrangements and levels of nitrogen.

iii) To assess the compatibility between wheat and grasspea / lentil as intercropping combination.

iv) To assess the economic validity of wheat & grasspea / lentil intercropping systems.

Chapter 2
REVIEW OF LITERATURE

An attempt has been made in this chapter to present a brief review of research in relation to intercropping of pulse crops with wheat to obtain better yield. Intercropping has many advantages for the farmers. It increases total production, acts as insurance against failure of the principal crop and better utilization of interspaces in crops. It reduces the cost of intercultural operation and increase the fertility of the soil. It gives higher land equivalent ratio and higher equivalent yield.

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 the total yield and returns in terms of unit land area.

Saxena (1972) conducted that crops of varying maturity needed to be chosen so that a quick maturing crop completes its life cycle before the grand period of growth of wheat crop.

Andrews (1972) observed that intercropping was found to be helpful to improve nutritional quality of diet allowed better control of weeds, decreased the incidence of insect pests, increased land equivalent ratio, reduced soil erosion and helped in the better use of sunlight and water (IRRI, 1973).

Andrews and Kassam (1976) concluded that the degree of spatial and temporal overlap in the two crops can vary somewhat, but both requirements must be met for a cropping system to be an intercrop. Numerous types of intercropping, all of which vary the temporal and spatial mixture to some degree, have been identified.

Dalrymple (1976) showed that net returns per unit area and return per unit time of work were increased by increasing cropping index even up to 300 following the intercropping technique.

Hasanuzzaman (1976) reported that the increased production of wheat and its acreage in Bangladesh, crop combination like wheat and potato; Tobacco and wheat; mustard and wheat; Flax and wheat, legume and wheat, etc. were shown to be encouraging.

Krarntz *et al.* (1976) concluded that mixed / intercropping legume and non- legume covered risk, earned more profit and stabilized production, improved soil fertility, conserved moisture and facilitated efficient labor distribution.

Trenbath (1976) expressed that the main advantage of using legumes in intercropping and mixed cropping was found to be the saving of nitrogen fertilizer.

Hoque *et al.* (1978) showed that mixed cropping of wheat - lentil and gram - mustard at various seed ratios found that wheat - gram gave the best production per unit area with 50 : 100 or 50 : 50 wheat - gram combinations giving about 50% increase in production.

Singh (1979) observed that sorghum gave maximum yield and monetary advantages when grown between paired rows of maize. He reported that components crops being grown in wider spaces of paired row system enable the plants to utilize efficiently the soil nutrients and solar radiation.

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).

Rathore *et al.* (1980) showed that paired planting of maize + blackgram at 30/60 cm using the inter paired space for growing blackgram, significantly increased the production and income compared with standard method of planting of maize at 60 cm row spacing.

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

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.

Waghmare *et al.* (1982) showed that legume should benefit in association with non-legume crops.

Sharma *et al*. (1982) conducted that LER measures the crop productivity of a unit area covered by a crop mixture vis-à-vis that of the sole component.

Singh (1983) reported that maximum benefit occurs when component crops are sown in wider row spaces for the tall crop component without reducing its plant population. Such spatial arrangement augments the utilization of available space, soil nutrients and solar radiation for the companion crops. Therefore technique of “paired row” planting has been developed to harness the maximum advantage from an intercropping system.

Singh and Singh (1983) reported that highest land equivalent ratio (1.27) was recorded in wheat and gram intercropping system followed by wheat + pea (1.19) and wheat + lentil (1.10).

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

Natarajan and Willey (1985) concluded that the yield advantages of intercropping due to better and over all use of resources by the companion crop.

Results analyzed that the LER value was influenced by many factors like density, morphology, competitive abilities, and growth duration and management etc. (Fawusi *et al.,* 1982)

Manson *et al*. (1986) reported that intercropping did not always increase the total yield. Sometimes it decreased the yield. Cassava yields were decreased by 2.3 to 4.7 t ha^{-1} when intercropped with cowpea or peanut.

Quayyum *et al*. (1987) stated that intercropping maize at row distances of 75, 100 and 125 cm with one, two and three rows of chickpea between maize rows. Two years data revealed intercropping of maize grown at a spacing of 75 x 25 cm with two rows of chickpea produced the highest total maize equivalent yield of 5590 kg ha^{-1}. This was 22% higher than the yield of sole crop of maize. Maize + chickpea, yield gave the highest net return of Tk. 12803 ha^{-1} and highest LER of 1.35 indicating that the mixture was 35% more efficient in terms of land utilization than sole crop of maize.

Palaniappan (1988) concluded that if the LER was equal to or less than one, it was considered to have no advantage of intercropping over monoculture in term of production. But if LER was more than one under intercropping was considered to have agronomic advantage over monoculture practice.

Singh *et al.* (1988) stated that combined yield of maize + legume was higher both at 1:1 and 1:2 rows than monoculture of maize. It was possibly due to increased yield of maize in addition to bonus yield of legumes.

Hiremath *et al*. (1989) reported that wheat grain yield was not affected by intercropping with soybean at 1:1 to 4:3 row ratios; however, soybean seed yield was reduced about 0.58 t ha^{-1} when intercropped. The highest land equivalent ratio (1.33) was obtained from intercropping wheat and soybean in a 1:2 row ratio and gross return from 3:1 row ratio.

Karim *et al.* (1990) to study the effect of planting system of maize with rows of groundnut grown as mono and / or intercrop. Maximum grain yield of maize (2.96 t ha^{-1}) was obtained from monoculture in uniform row which was identical to maize uniform row, with two or three rows of groundnut. Higher maize and wheat equivalent yield was found in uniform 3 or paired 6 rows of groundnut. Both the former and later combination gave higher LER (1.44) and net return of Tk. 8719 and 8502 ha^{-1}, having same benefit cost ratio.

Patra *et al.* (1990) described that the association of soybean gave the highest combined yield at both 1:1 and 1:2 row ratios, whereas the association between maize and sesame recorded the lowest combined yield due to severe competition.

Dhingra *et al*. (1991) reported that maize and mungbean under different planting patterns and row orientation where higher maize yield was obtained from intercropping system. The result of the experiment in maize yield was attributed to the complementary effect of mungbean in terms of biological nitrogen fixation.

Atar *et al.* (1992) demonstrated a field experiment at New Delhi with wheat based intercropping system. They reported that intercropping system ensured highest water use efficiency.

Nag *et al.* (1996) described that monoculture of maize, cowpea, khesari, mungbean, groundnut and maize intercropped with legumes in paired rows were compared in an experiment conducted during 1993-94, highest maize equivalent yield (6973 kg ha^{-1}) was obtained from maize + mungbean intercropping, but maize + groundnut combination gave highest maize equivalent yield (5615 kg ha^{-1}) in 1994-95. Maize + mungbean and maize + groundnut also gave highest net return (Tk. 50952 ha^{-1} and Tk. 40245 ha^{-1}) during 1993-94 and 1994-95, respectively. On an average maize + cowpea and maize + khesari combination gave the highest benefit cost ratio (5.34 and 5.32) and land equivalent ratio (1.35).

Singh *et al.* (1992) described that the monetary advantage evaluated over sole wheat indicated a positive gain from intercropping system. Maximum monetary advantage was recorded from wheat + grasspea in 3:1 row ratio followed by the same crops with 1:1 row ratio. Sole crops failed to give maximum net return. It appeared that wheat, mustard and grasspea was less benefited under sole cropping. Wheat when grown with grass pea gave 24 to 46% higher monetary advantages over sole wheat.

Shafi *et al.* (1993) observed that wheat grain yield was 2.47 t ha^{-1} in the pure stand and 1.62, 1.81 and 2.14 t ha^{-1} when intercropped in 2, 3 or 4 row strips, respectively with safflower. Safflower seed yield was 0.34 t ha^{-1} in the pure stand and 0.03 - 0.08 t ha^{-1} when intercropped. Cost - benefit ratio was highest from the intercrop using strips of 3 rows of the each crop.

Alteieri (1994) stated that intercropping of compatible plants also encourages biodiversity, by providing a habitat for a variety of insects and soil organisms that would not be present in a single intercrop environment. This biodiversity can in turn help to limit outbreaks of crop pests.

Nazir *et al*. (1994) found that in monetary term, both the wheat - fenugreek and wheat - lentil intercropping systems proved to be more beneficial than the other cropping systems including monocropped wheat.

Banik (1994) evaluated that wheat and legume intercropping under 1:1 and 2:1 row ratios and found that the wheat peas intercropping (1:1) gave the highest wheat yield equivalent of 3.02 t ha^{-1} followed by the wheat - lentil intercropping (2.91) which also gave the highest monetary returns.

Carr *et al.* (1995) observed that LER value was 1.15 for sole cropping while they had an experiment of wheat-lentil intercropping.

Singh and Sarawgi (1995) found that the effect of row ratio nitrogen and irrigation in wheat-chickpea intercropping system with row ratios of 2:1 2:2. The best intercropped treatment was where the crops were grown in using the row ratio of 2:1.

Verma *et al*. (1997) observed that wheat and lentils grown alone or intercropped in a 4: 2 row ratio. The wheat in pure stand was given 80 kg N + 16kg P + 16 kgha^{-1} (100% NPK), while sole lentil received 20 kg N + 16 kg P ha^{-1} (100% NP). Intercrops were given 8 different combinations of fertilizers. Wheat grain yield was 3.29 t ha^{-1} in pure stand and 2.73 - 3.12 t ha^{-1} when intercropped. Lentil seed yield was 1.53 t ha^{-1} in pure stand and 0.22 - 0.41 t ha^{-1} when intercropped. The highest wheat-equivalent yield and net returns were obtained when wheat with 100% NPK and intercropped with lentils fertilized with 75% NP.

Alam *et al.* (1997) stated that wheat + chickpea, wheat + lentils and wheat + peas reduced the total weed population by 26, 12 and 28% and weed biomass by 31, 13 and 27% respectively, compared to the wheat monoculture.

Tomar *et al.* (1997) demonstrated a field trial on sandy loam soil in winter seasons where wheat was grown alone or intercropped with *Lens culinaris and Cicer arietinum* in 2: 2 or 3: 2 row ratios. Seed yields of all crops were decreased by intercropping. Total plant N content was highest in *Lens culinaris* grown alone increasing N fertilizer rate (0 - 90 kg N ha^{-1}) increased wheat grain yield but did not generally affect legume seed yields.

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

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. It was also reported that practicing wheat and pulse intercropping reduced the total weed population significantly compared to the wheat monoculture.

Ahmed and Saeed (1998) demonestred an experiment on wheat and lentil intercropping at row ratios of 4: 3, 5:3, 8:3 or 10:3.Wheat grain yield was highest

(4040 kg ha^{-1}) with the 10:3 row ratios. This treatment produced lentil seed yield of 441 kg ha^{-1}. The second highest yield was obtained form 8:3 ratio whereas wheat was 3760 kg and lentil was 481 kg ha^{-1}.

Malik *et al*. (1998) demonestred a field trial with wheat grown alone or intercropped with lentils, gram or rape. Grain yield of wheat was decreased by 371, 420 and 388 kg ha^{-1} with intercropping of lentil, gram and rape, respectively. However, losses in wheat yield were compensated by increased income from the intercrops. The highest net income with a benefit - cost ratio (2.75) was obtained from wheat - lentil intercropping compared with a BCR of 2.35 for wheat alone.

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

Rahman (1999) described that intercropping of grass pea and yellow sarson with wheat was sustainable over sole wheat. The association of wheat with grass pea under either 3:1 or 1:1 was more sustainable, which accounted for better value with respect to biological parameters and was economically more remunerative.

Rahman (1999) and Miah (1982) showed that wheat and grasspea intercropping proved as sustainable over sole crop.

Thakur *et al.* (2000) demonstrated that chickpea + safflower intercropping in 3:1 and 6:2 row ratios were superior to pure stands of either crop components and to chickpea + mustard and chickpea + linseed.

Ashok *et al.* (2001) found that number of tillers per plant of wheat was not significantly affected by wheat based intercropping system.

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

Nargis and Krishna (2003) showed that weed was significantly controlled by wheat + sunflower and wheat + linseed at 3:1 and 3:1 row ratios, respectively.

Nargis *et al*. (2004) conducted an experiment on mixed cropping of lentil (100%) and wheat (20, 40, 60 or 80%). It was showed 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 maximum number of seeds per plant (47) and seed yield (1278 kg ha^{-1}) of lentil were obtained under line sowing. Sole wheat (broadcast) produced the tallest plants (89.15 cm) and the longest spikes (9.84 cm). The highest land equivalent ratio (1.52), monetary advantage and benefit: cost ratios (1.84) were recorded for intercropping lentil (100%) and wheat (40%). They also reported that the highest seed yield (2704 kg ha^{-1}) was obtained under line sowing of sole wheat.

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

Ullah (2007) conducted that higher combined yield, net return, BCR and LER over sole wheat when broadcasted chickpea in between two paired rows of wheat.

Sultana (2007) showed that the highest LER, combined yield, net return and BCR was obtained while wheat + grasspea cultivated under mixed cropping systems.

Hossain *et al.* (2010) calculated higher net return (Tk. 14452 ha^{-1}) and benefit cost ratio (3.06) where they maintain two rows of wheat alternate with one row chickpea with 40-30-20 N, P_2O_5, K_2O Kg ha^{-1}, respectively in a wheat + chickpea intercropping experiment. They also reported that, two rows wheat alternate with one row chickpea gave highest land equivalent ratio(1.29), wheat equivalent yield (3.13 t ha^{-1}), net return (Tk. 164330 ha^{-1}) and benefit cost ratio (4.13) followed by that of 3 : 2 combination in another intercropping experiment.

Khatun (2010) reported that highest LER, gross return, net return, equivalent yield, benefit cost ratio and monetary advantages. She also showed that the planting pattern of one row grasspea fitted in between two paired rows of wheat gave an increase of

1.59% of total grain yield, 84.37% net income, BCR 1.71 and LER 1.38 over normal planting of wheat that compensated losses in wheat yield under intercropping system.

From the above findings it is clear that the intercropping system has advantages in regards of land use, greater yield, monetary benefit etc. The paired row wheat in combination with pulse like grasspea or lentil plays an important role to bring back pulse cultivation in the main land without using extra land.

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 farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during the period from November, 2009 to March, 2010 to study the intercropping of wheat paired row with grasspea and lentil under different levels of nitrogen.

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 5.70. Organic matter content was medium (2.35%).

3.3 Climate and weather

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) is shown in Appendix II.

3.4 Planting materials

Three types of crops having dissimilar growth habits were used in this experiment. The crops were wheat (*Triticum aestivum*), grasspea (*Lathyrus sativus*) and lentil (*Lens culinaris*). In this experiment wheat was grown as main crop and grasspea and lentil were grown as companion crop.

3.5 Plant characteristics and variety

3.5.1 Wheat

A high yielding variety of wheat BARI gom-19 (Shourav) was selected as planting materials. The variety was released by WRC (Wheat Research Centre) of BARI in 1998. This variety is suitable for growing all over the country. This variety is also suitable for late sowing. It completes its life cycle within 102-110 days. The height of the plant is 90-100 cm. It produces 5-6 tillers plant^{-1}. The stem is hard enough and does not lodge in wind and storm. Leaves are flat, droopy and deep green. Flag leaf is wide and droopy in nature. The number of spikelet spike^{-1} is 42 - 48 and size of grains are medium to large and the color of the grains is white. The weight of 1000 seed is 40-45 g. Plant requires 60-70 days to emerge spike. It has ability to give 3.5-4.6 t ha^{-1} in favorable condition. This variety is tolerant to leaf spot and leaf rust diseases. This variety is heat tolerant that is why in case of late sowing it gives better yield. The variety gives 10-12% more yield than the traditional variety (BARI, 2005).

3.5.2 Grasspea

BARI khesari-2 is a high yielding grasspea variety was selected as planting material. This variety was released by BARI in 1996 .The height of the plant is 55-60 cm. The leaf is broader than the local variety and color of the flower is blue. The size of the seed is slightly larger and weight of 1000 seed is 50-55 g. The color of the seed is slightly grey. Seed contains about 24-26% protein. It requires 125-130 days from sowing to maturing / ripening. The average yield of this variety is 1.5-1 t ha^{-1}(BARI, 2005).

3.5.3 Lentil

A high yielding variety of lentil namely BARI masur-4 was selected as planting material. This variety was released by BARI in 1996.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 1.6-1.7 tha^{-1} (BARI, 2005).

3.6 Experimental treatments

The experiment had 14 treatments of different intercropping of wheat with grasspea and lentil. The treatments were as follows –

T_1 = Wheat normal row + 100kg N ha^{-1}

T_2 = Wheat paired row (WPR) + 100kg N ha^{-1}

T_3 = Sole grasspea + 20kg N ha^{-1}

T_4 = Sole lentil + 20kg N ha^{-1}

T_5 = WPR + 1 row grasspea + 80kg N ha^{-1}

T_6 = WPR + 1 row grasspea + 100kg N ha^{-1}

T_7 = WPR + 1 row grasspea + 120kg N ha^{-1}

T_8 = WPR + 1 row lentil + 80kg N ha^{-1}

T_9 = WPR + 1 row lentil + 100kg N ha^{-1}

T_{10} = WPR + 1 row lentil + 120kg N ha^{-1}

T_{11} = Wheat + lentil (3:1) + 80kg N ha^{-1}

T_{12} = Wheat + lentil (3:1) + 100kg N ha^{-1}

T_{13}= Wheat + lentil (3:1) + 120kg N ha^{-1}

T_{14}= Wheat + grasspea (3:1) +100kg N ha^{-1}

3.6 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 14 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 wheat was sown maintaining row spacing as 20 cm. The seeds were sown as continuous in each line following the seed rate. Sole grasspea / lentil were sown maintaining line and plant spacing as 30 cm X 10 cm, respectively. The wheat paired row was created as two wheat line brought close together with 10 cm line spacing. Thus 40 cm free space was obtained between two wheat paired rows (WPR). In case of T_5 , T_6 ,T_7 , T_8 , T_9 ,T_{10} treatment, one row grasspea / lentil was fitted between two WPR. In T_{11}, T_{12}, T_{13}, T_{14} treatment, 3: 1 row ratio of wheat and grasspea / lentil one row grasspea / lentil was fitted after three rows of wheat.

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 November 10, 2009 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 November 14, 2009. The layout was done as per experimental design on November 15, 2009.

3.8.2 Fertilizer application

For sole wheat fertilizers were applied at the rate of 100, 80, 30 and 20 kg ha^{-1} of NPK and S respectively. 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 crown root initiation stage (21 DAS) with one irrigation.

In case of sole grasspea and lentil fertilizers were applied at the rate of 20, 40, 20 and 7 kg ha^{-1} of NPK and S respectively. The entire amount of urea, TSP, MP & gypsum were applied as basal dose.

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

3.8.3 Seed collection and sowing

The wheat seeds (cv. Shourav) were collected from wheat research centre of Bangladesh Agricultural Research Institute (BARI), at Joydebpur, Gazipur and the grasspea seeds (BARI khesari-2) were collected from pulse and oil seeds center from the same institute. The lentil seeds (BARI masur-4) were collected from Bangladesh Agricultural Development Corporation (BADC).

Seeds were treated with Vitavax 200 @ the rate of 3 g kg^{-1} of seeds and sown in line on November 16, 2009 as per experimental treatments. The recommended seed rate of wheat grasspea and lentil were 120 kg, 50 kg and 35 kg ha^{-1}, respectively. After sowing the seeds were covered with loose friable soil. Two guards were appointed from early morning to evening to protect the seeds from birds.

3.8.7 Germination test

Germination test was performed before sowing the seeds in the field. Filter papers were placed on four Petri dishes and the papers were soaked with water where 25 seeds were placed at random in each Petri dish. Data on germination were determined as percentage basis by using the following formula:

$$\text{Germination test (\%)} = \frac{\text{Number of germinated seeds}}{\text{Number of seeds set for germination}} \times 100$$

3.8.6 Weeding

Weeds were controlled through three weedings at 23, 38, 50 days after sowing (DAS). The weeds identified were Kakpaya ghash (*Dactyloctenium aegyptium* L), Shama (*Echinocloa crussgalli*), Durba (*Cynodon dactylon*), Arail (*Leersis hexandera*), Mutha (*Cyperus rotundus* L), Bathua (*Chenopodiunm album*), Shaknatey (*Amaranthus viridis*), Foska begun (*Physalis beteophylls*), Titabegun (*Solanum torvum*) and Shetlomi (*Gnaphalium luteolabum* L).

3.8.5 Irrigation

Germination of seeds was ensured by light irrigation. Two irrigations were given, first irrigation was given (23 DAS) at crown root initiation stage and second irrigation was given (53 DAS) at the heading stage. During irrigation care was taken so that water could not flow from one plot to another or overflow the boundary of the plots. Excess water of the field was drained out.

3.8.9 Harvesting and sampling

At full maturity, the wheat, grasspea and lentil crops were harvested plot wise on March 10, 2010. Crop of each plot was harvested from 3.75 m^2 separately for yield of seed. 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 Wheat

1. Plant height (cm) from 20 DAS to harvest
2. Above ground dry matter plant $^{-1}$ (g) from 20 DAS to harvest
3. Number of tillers m^{-2} from 40 DAS to harvest
4. Length of spike (cm) from 60 DAS to harvest
5. Spikelets spike^{-1} (cm) from 60 DAS to harvest
6. 1000 grain weight (g)
7. Grain yield (t ha^{-1})
8. Harvest index (%)

3.9.2 Grasspea

1. Plant height (cm) from 20 DAS to harvest
2. Above ground dry matter plant $^{-1}$ (g) from 20 DAS to harvest
3. Number of branches plant^{-1} from 40 DAS to harvest
4. Number of pods plant^{-1}
5. 1000 seed weight (g)
6. Seed yield (t ha^{-1})
7. Biological yield (t ha^{-1})
8. Harvest index (%)

3.9.3 Lentil

1. Plant height (cm) from 20 DAS to harvest
2. Above ground dry matter plant $^{-1}$ (g) from 20 DAS to harvest
3. Number of branches plant^{-1} from 40 DAS to harvest
4. Number of pods plant^{-1}
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. The detail outline of data recording is given below:

3.10.1 Wheat

3.10.1.1 Plant height (cm)

The heights of 10 plants were measured from the ground level to tip of the plants and than averaged.

3.10.1.2 Above ground dry matter plant^{-1} (s)

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

3.10.1.3 Number of tillers m^{-2}

One meter square scale was placed in each plot randomly and then total number of tillers are calculated. It was taken from 40 DAS to harvest.

3.10.1.4 Length of spike (cm)

Lengths of spike were measured from 10 plants in each plot and then averaged.

3.10.1.5 Spikelets spike $^{-1}$

The numbers of spikelet spike^{-1} were measured from 10 plants in each plot and then averaged.

3.10.1.6 Weight of thousand grain (g)

One thousand cleaned dried seeds were counted randomly from each harvested sample and weighed by using digital eclectic balance.

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

Wheat was harvested randomly from 3.75 m^2 area of land of each plot. Then the harvested wheat was 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}.

3.10.1.8 Harvest Index (%)

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

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

3.10. 2 Grasspea and lentil

3.10.2.1 Plant height (cm)

The heights of 10 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} (s)

Ten plants were collected at different days after sowing (20, 40, 60, 80, 100 DAS and at 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. It was taken from 40 DAS to harvest.

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 (g)

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 (t ha^{-1})

Grasspea and lentil was harvested randomly from 3.75 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.

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

3.11 Relative yield and land equivalent ratio (LER)

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).

$$\text{Relative yield of wheat} = \frac{\text{Intercrop yield of wheat}}{\text{Sole crop yield of wheat}}$$

$$\text{Relative yield of grasspea} = \frac{\text{Intercrop yield of grasspea}}{\text{Sole crop yield of grasspea}}$$

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

Land equivalent ratio (LER) = Relative yield of wheat + Relative yield of grasspea / 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, 1979a).

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

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

$$\text{Wheat equivalent yield} = Y_w + \frac{Y_g \times P_g}{P_w} \quad \text{or,} \quad Y_w + \frac{Y_l \times P_l}{P_w}$$

(For intercropping)

Where,

Y_w = Seed yield of wheat (intercrop) (t ha^{-1})

Y_g = Seed yield of grasspea (intercrop) (t ha^{-1})

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

P_g = Market price of grasspea seed (Tk. 50 kg^{-1})

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

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

Similarly,

$$\text{Grasspea equivalent yield} = Y_g + \frac{Y_w \times P_w}{p_g}$$

(For intercropping)

Where,

Y_w = Seed yield of wheat (intercrop) (t ha^{-1})

Y_g = Seed yield of grasspea (intercrop) (t ha^{-1})

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

P_g = Market price of grasspea seed (Tk. 50 kg^{-1})

Similarly,

$$\text{Lentil equivalent yield} = Y_l + \frac{Y_w \times P_w}{P_l}$$

(For intercropping)

Where,

Y_w = Seed yield of wheat (intercrop) (t ha^{-1})

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

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

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

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

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

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

Where, LER= Land Equivalent Ratio

3.14 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.

3.15 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.

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

3.16 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 effect of intercropping of wheat with grasspea / lentil under different levels of nitrogen. 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 Wheat

4.1.1 Growth attributes of wheat

4.1.1.1 Plant height (cm)

Plant height of wheat was significantly affected by the intercropping with grasspea / lentil under different levels of nitrogen. Plant height increased with the advancement of plant age (Fig. 1).

At 20 DAS, the tallest plant (22.53 cm) was obtained from T_{12} treatment and the shortest plant was obtained from T_2 treatment (17.63 cm) which was statistically similar with $T_{1,}$ $T_{8,}$ T_9 and T_{10} treatments. At 40 DAS, highest plant height (43.10 cm) was obtained from T_{13} which was statistically similar with $T_{1,}$ $T_{7,}$ and T_{10} treatments and the lowest (36.50 cm) was obtained from T_9 treatment which was statistically similar with $T_{2,}$ $T_{3,}$ $T_{8,}$ and T_{11} treatments.

At 60 DAS, T_{12} treatment resulted in highest plant height (69.20 cm), which was statistically similar with $T_{7.}$ The lowest plant height (58.78g cm) was obtained from T_8 treatment and it was statistically similar with $T_{9,}$ T_{10} and T_{14} treatments.

At 80 DAS, the highest plant height 81.46 cm was obtained from T_2 treatment which was statistically similar with $T_{6,}$ $T_{13,}$ and T_{11} treatments whereas lowest plant height 72.29 cm was obtained from T_1 which was statistically similar with $T_{5,}$ $T_{9,}$ T_{10} and T_{11} treatments, respectively.

At 100 DAS, the highest plant height 83.90 cm was obtained from T_{13} treatment which was statistically similar with $T_{6,}$ $T_{12,}$ and T_{14} treatments and lowest plant height 76.00 cm was obtained from T_8 which was statistically similar with $T_{2,}$ $T_{5,}$ T_{10} and T_{11} treatments.

At final harvest, the tallest plant (81.85 cm) was observed in T_{13} treatment which was statistically similar with $T_{1,}$ $T_{6,}$ $T_{7,}$ $T_{9,}$ T_{12} and T_{14} treatments. The shortest plant (75.09 cm) was observed in T_5 treatment, which was statistically similar with T_8 and T_{10} treatments.

Islam (2006) reported that, plant height of wheat varied significantly due to intercropping system. Pratibha *et al.* (2000) demonstrated an experiment on the growth parameters of sunflower intercropped with pea, linseed, niger and gram under 1:1 and 1:2 row intercropping during winter season and showed that height of sunflower plants were almost identical under both intercropping and sole cropping.

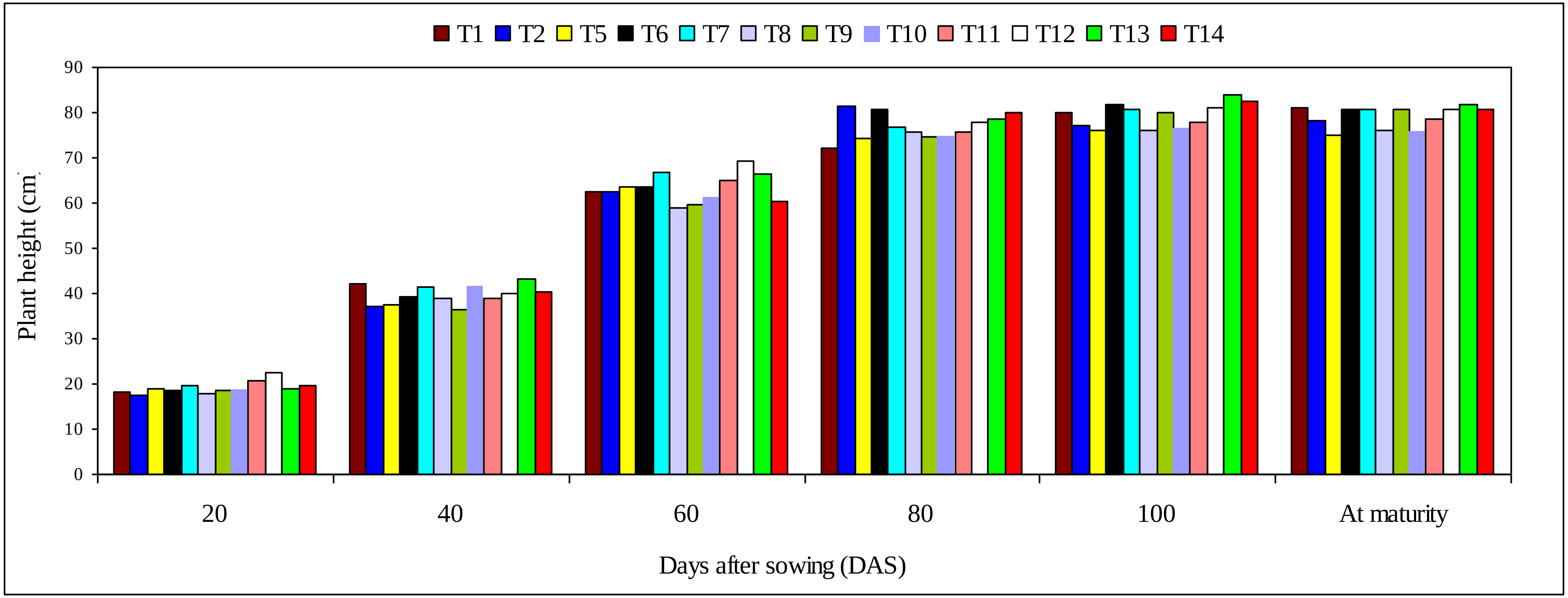

Fig. 1. Plant height (cm) of wheat at different days under different intercropping systems ($LSD_{0.05}$ = 0.96, 2.69, 2.74, 3.30, 3.01, 2.60 at 20, 40, 60, 80, 100 DAS and harvest, respectively)

T_1 = Wheat normal row + 100kg N ha^{-1}
T_2 = Wheat paired row (WPR) + 100kg N ha^{-1}
T_5 = WPR + 1 row grasspea + 80kg N ha^{-1}
T_6 = WPR + 1 row grasspea + 100kg N ha^{-1}
T_7 = WPR + 1 rows grasspea + 120kg N ha^{-1}
T_8 = WPR + 1 row lentil + 80kg N ha^{-1}
T_9 = WPR + 1 row lentil + 100kg N ha^{-1}
T_{10} = WPR +1 row lentil + 120kg N ha^{-1}
T_{11} = Wheat + lentil (3:1) + 80kg N ha^{-1}
T_{12} = Wheat + lentil (3:1) + 100kg N ha^{-1}
T_{13}= Wheat + lentil (3:1) + 120kg N ha^{-1}
T_{14}= Wheat + grasspea (3:1) +100kg Nha^{-1}

4.1.1.2 Above ground dry weight plant^{-1} (g)

Above ground dry matter weight of wheat was significantly affected by intercropping with grasspea / lentil under different levels of nitrogen (Table 1). It increased with the advancement of plant age.

At 20 DAS, the highest dry matter of wheat (0.13 g) was obtained from T_{12} treatment and the lowest dry matter (0.06 g) was obtained from T_1 treatment. At 40 DAS, the highest dry matter weight of wheat (1.00 g) obtained from T_{13} treatment and the lowest dry matter (0.57g) was obtained from T_2 treatment and it was statistically similar with T_1, T_8 and T_9 treatment.

At 60 DAS, the highest dry weight of wheat was obtained from T_{13} (2.10 g) treatment and the lowest dry weight was found from T_{10} (1.44 g) and it was statistically similar with T_9 treatment. At 80 DAS, the maximum dry weight of wheat was obtained from T_{12} treatment (7.72 g) and it was statistically similar with T_{13} and T_{14} treatment. The minimum dry matter was obtained from T_2 treatment (4.96 g).

At 100 DAS, the highest dry matter (9.30 g) was recorded from T_{14} treatment. The lowest dry matter (6.48 g) was obtained from T_9 treatment. At maturity, the highest dry matter of wheat was obtained from T_{14} treatment (10.09 g). The lowest dry matter (7.08 g) was obtained from T_9 treatment.

Irrespective of treatment difference the dry matter production of wheat was slow upto 40 DAS then increased with time and got pick at harvest. It was appeared that the above ground dry matter increases in sole wheat treatment at all growth stages except 60, 80 and at maturity when it was intercropped with grasspea / lentil. Probably the wheat plants were influenced for higher accumulation of above ground dry matter when it grew in association legume crop.

However, dissimilar findings were also found by Islam (2006) who showed that dry matter weight of wheat was significantly affected by intercropping system.

Table 1: Dry matter accumulations (g plant^{-1}) of wheat at different days as influenced by different intercropping systems with grasspea / lentil

Treatments	DAS					At harvest
	20	**40**	**60**	**80**	**100**	
T_1	0.06	0.59	1.93	6.03	8.06	8.79
T_2	0.09	0.57	1.80	4.96	7.31	7.98
T_5	0.08	0.65	1.70	6.06	7.14	7.87
T_6	0.10	0.65	1.96	5.90	7.24	7.65
T_7	0.10	0.76	1.95	6.34	7.88	9.31
T_8	0.09	0.58	1.29	5.97	7.14	8.04
T_9	0.11	0.59	1.46	6.39	6.48	7.08
T_{10}	0.07	0.70	1.44	5.75	7.94	8.04
T_{11}	0.09	0.73	1.96	6.10	7.21	7.87
T_{12}	0.13	0.67	1.86	7.72	8.13	8.98
T_{13}	0.12	1.00	2.10	7.50	8.18	8.87
T_{14}	0.09	0.66	1.92	7.50	9.30	10.09
$LSD_{(0.05)}$	0.053	0.054	0.131	0.487	0.764	0.574
CV (%)	9.21	5.14	4.31	4.54	5.89	4.05

T_1 = Wheat normal row + 100kg N ha^{-1}
T_2 = Wheat paired row (WPR) +100kg N ha^{-1}
T_5 = WPR + 1 row grasspea + 80kg N ha^{-1}
T_6 = WPR + 1 row grasspea + 100kg N ha^{-1}
T_7 = WPR + 1 rows grasspea + 120kg N ha^{-1}
T_8 = WPR + 1 row lentil + 80kg N ha^{-1}
T_9 = WPR + 1 row lentil + 100kg N ha^{-1}
T_{10} = WPR +1 row lentil + 120kg N ha^{-1}
T_{11} = Wheat + lentil (3:1) + 80kg N ha^{-1}
T_{12} = Wheat + lentil (3:1) + 100kg N ha^{-1}
T_{13}= Wheat + lentil (3:1) + 120kg N ha^{-1}
T_{14}= Wheat + grass pea (3:1) +100kg N ha^{-1}

4.1.1.3 Number of tillers m^{-2}

The number of tillers per square meter of wheat was affected significantly due to different intercropping system (Table 2). At 40 DAS, the highest number of tillers m^{-2} of wheat was obtained from T_1 (66.22) treatment which was statistically similar with T_6 and T_7 treatments. The lowest number of tillers m^{-2} was obtained from T_{14} (40.13) treatment.

At 60 DAS, the maximum number of tillers m^{-2} of wheat (70.67) was obtained from T_2 treatment which was statistically similar with T_7 treatment. The minimum number of tillers m^{-2} (50.60) was obtained from T_{11} treatment.

At 80 DAS, the highest number of tillers m^{-2} of wheat (75.22) was obtained from T_1 treatment. The lowest number of tillers m^{-2} (42.87) was obtained from T_{11} treatment which was statistically similar with T_{12} treatment.

At 100 DAS, the maximum tillers m^{-2} of wheat (75.22) was reordered from T_1 treatment. The minimum (45.00) number of tillers m^{-2} was reordered from T_{12} treatment.

At maturity, the highest (75.15) number of tillers m^{-2} of wheat was shown in T_1 treatment while the lowest number (44.67) from T_{12} treatment.

Table 2: Number of tillers m^{-2} of wheat at different days under different intercropping systems with grasspea / lentil

Treatments	**DAS**				At harvest
	40	**60**	**80**	**100**	
T_1	66.22	66.55	75.22	75.15	75.22
T_2	52.44	70.67	71.73	71.90	71.90
T_5	46.61	57.02	62.35	64.57	64.72
T_6	65.01	64.17	63.08	64.04	65.14
T_7	65.51	69.86	65.78	66.00	66.04
T_8	51.74	62.58	60.88	60.00	60.00
T_9	56.54	64.88	62.30	58.75	61.45
T_{10}	52.62	64.44	65.24	65.24	65.24
T_{11}	46.80	50.60	42.87	48.80	48.80
T_{12}	41.40	55.80	43.67	45.00	45.00
T_{13}	44.14	61.01	52.60	52.87	52.87
T_{14}	40.13	55.40	49.60	50.26	50.26
$LSD_{(0.05)}$	3.443	3.220	1.799	3.145	1.992
CV (%)	3.88	3.07	1.78	3.08	1.95

T_1 = Wheat normal row + 100kg N ha^{-1}
T_2 = Wheat paired row (WPR) + 100kg N ha^{-1}
T_5 = WPR + 1 row grasspea + 80kg N ha^{-1}
T_6 = WPR + 1 row grasspea + 100kg N ha^{-1}
T_7 = WPR + 1 rows grasspea + 120kg N ha^{-1}
T_8 = WPR + 1 row lentil + 80kg N ha^{-1}
T_9 = WPR + 1 row lentil + 100kg N ha^{-1}
T_{10} = WPR +1 row lentil + 120kg N ha^{-1}
T_{11} = Wheat + lentil (3:1) + 80kg N ha^{-1}
T_{12} = Wheat + lentil (3:1) + 100kg N ha^{-1}
T_{13}= Wheat + lentil (3:1) + 120kg N ha^{-1}
T_{14}= Wheat + grass pea (3:1) +100kg N ha^{-1}

4.1.2 Yield attributes of wheat

4.1.2.1 Length of spike (cm)

Spike length of wheat was significantly affected at harvest by different intercropping system (Table 3).

The highest spike length of wheat (8.25 cm) was recorded with T_6 treatment which was statistically similar with T_8 treatment and the minimum (6.87 cm) from T_{12} which was statistically similar with T_2 treatment at 60 DAS.

At 80 DAS, the highest spike length of wheat (8.93 cm) was recorded with T_8 , which was statistically similar with T_{13} and T_{14} treatment and the minimum (7.12 cm) from T_2 , which was statistically similar with T_5, T_6, T_7, T_9, T_{10} and T_{11} treatments.

At 100 DAS, the highest spike length of wheat (14.15 cm) was obtained from T_1, which was statistically similar with T_7, T_9 and T_{13} treatments. The lowest length of spike of wheat (11.53 cm) was obtained from T_{14}, which was statistically similar with T_{11} treatments.

At maturity, the highest spike length of wheat (15.67 cm) was obtained from T_9 treatment followed by T_1, T_8 and T_{13} treatment. The lowest length of spike of wheat was obtained from T_2 treatment (13.55 cm) which was statistically similar with T_5, T_{10} , T_{11}, and T_{12} treatments. Ghanbari and Lee (2002) and Nargis *et al*. (2004) showed significant effect of intercropping on the length of spike of wheat.

Table 3: Spike length (cm) of wheat at different days as influenced by different intercropping systems with grasspea / lentil

Treatments	DAS			At harvest
	60	80	100	
T_1	7.76	8.05	14.15	15.11
T_2	6.84	7.12	12.65	13.55
T_5	7.05	7.20	11.76	13.87
T_6	8.25	7.40	12.34	14.67
T_7	7.26	7.24	13.55	14.52
T_8	7.87	8.93	11.98	15.07
T_9	6.92	7.48	13.56	15.67
T_{10}	7.53	7.67	12.76	14.06
T_{11}	6.22	7.46	11.23	14.44
T_{12}	6.87	7.81	12.22	13.86
T_{13}	6.93	8.38	13.65	15.65
T_{14}	7.57	8.39	10.53	14.56
$LSD_{(0.05)}$	0.673	0.584	0.785	0.936
CV (%)	5.48	4.45	3.70	3.79

T_1 = Wheat normal row + 100kg N ha^{-1}
T_2 = Wheat paired row (WPR) + 100kg N ha^{-1}
T_5 = WPR + 1 row grasspea + 80kg N ha^{-1}
T_6 = WPR + 1 row grasspea + 100kg N ha^{-1}
T_7 = WPR + 1 rows grasspea + 120kg N ha^{-1}
T_8 = WPR + 1 row lentil + 80kg N ha^{-1}
T_9 = WPR + 1 row lentil + 100kg N ha^{-1}
T_{10} = WPR +1 row lentil + 120kg N ha^{-1}
T_{11} = Wheat + lentil (3:1) + 80kg N ha^{-1}
T_{12} = Wheat + lentil (3:1) + 100kg N ha^{-1}
T_{13}= Wheat + lentil (3:1) + 120kg N ha^{-1}
T_{14}= Wheat + grass pea (3:1) +100kg N ha^{-1}

4.1.2.2 Number of spikelets spike^{-1}

The number of spikelets spike^{-1} of wheat was significantly affected different intercropping system with grasspea / lentil (Table 4). At 60 DAS, the highest number of spikelets spike^{-1} of wheat (15.18) was obtained from T_9 treatment followed by T_6 treatment. The lowest number of spikelets spike^{-1} of wheat (10.61) was obtained from T_7 treatment.

At 80 DAS, the highest number of spikelets spike^{-1} of wheat (18.93) was shown in T_9 treatment which was statistically similar with $T_{6,}$ T_{13} and T_{14} treatments. The lowest number of spikelets spike^{-1} of wheat (14.00) was shown in T_2 treatment.

At 100 DAS, the highest (19.66) number of spikelets spike^{-1} of wheat was obtained from T_{14} treatment which was statistically similar with T_9 treatment. The lowest number of spikelets spike^{-1} of wheat (15.63) was obtained from T_7 treatment followed by T_2 and T_{11} treatments.

At maturity the highest number of spikelets spike^{-1}of wheat (20.19) was observed in T_9 treatment which was statistically similar with $T_{2,}$ $T_{7,}$ T_{10} and T_{14} treatments and the lowest (15.98) from T_7 treatment followed by T_5 and T_{11} treatments.

Table 4: Spikelets spike^{-1} of wheat as influenced by different intercropping systems with grasspea / lentil

Treatments	DAS			At harvest
	60	80	100	
T_1	14.02	15.55	16.59	17.29
T_2	12.67	14.00	16.19	18.98
T_5	13.40	16.10	16.60	16.98
T_6	14.72	17.78	18.74	19.79
T_7	10.61	15.35	15.63	15.98
T_8	13.33	16.36	17.90	18.86
T_9	15.18	18.93	19.19	20.19
T_{10}	11.89	16.01	18.80	19.00
T_{11}	13.97	15.66	16.23	17.08
T_{12}	13.87	16.80	17.22	17.76
T_{13}	14.00	18.78	18.60	18.78
T_{14}	14.60	18.74	19.66	19.98
LSD$_{(0.05)}$	0.673	1.344	0.851	1.360
CV (%)	2.94	4.76	2.86	4.37

T_1 = Wheat normal row + 100kg N ha^{-1}
T_2 = Wheat paired row (WPR) + 100kg N ha^{-1}
T_5 = WPR + 1 row grasspea + 80kg N ha^{-1}
T_6 = WPR + 1 row grasspea + 100kg N ha^{-1}
T_7 = WPR + 1 rows grasspea + 120kg N ha^{-1}
T_8 = WPR + 1 row lentil + 80kg N ha^{-1}
T_9 = WPR + 1 row lentil + 100kg N ha^{-1}
T_{10} = WPR +1 row lentil + 120kg N ha^{-1}
T_{11} = Wheat + lentil (3:1) + 80kg N ha^{-1}
T_{12} = Wheat + lentil (3:1) + 100kg N ha^{-1}
T_{13}= Wheat + lentil (3:1) + 120kg N ha^{-1}
T_{14}= Wheat + grass pea (3:1) +100kg N ha^{-1}

4.1.2.3 Thousand grain weight (g)

Thousand grain weight of wheat was significantly affected by different intercropping system (Table 5). Maximum thousand grain weight (42.40 g) of wheat was recorded in T_{11} treatment (3:1 row ratio of wheat and lentil with 80 kg N ha^{-1}) which was statistically similar with $T_{5,}$ $T_{8,}$ T_{10} $T_{12,}$ and T_{14} treatments. The lowest grain weight (39.50 g) was found with T_9 treatment and it was statistically similar with $T_{1,}$ $T_{2,}$ $T_{5,}$ $T_{6,}$ T_7 and T_{13} treatment. Nargis *et al.* (2004) showed that 1000 grain weight of wheat varied significantly with intercropping.

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

Grain yield of wheat was affected significantly by different intercropping system of wheat with grasspea / lentil (Table 5). The highest grain yield (3.41t ha^{-1}) of wheat was obtained from T_2 treatment and the lowest (2.31 t ha^{-1}) from T_8 treatment, which was statistically similar with $T_{5,}$ $T_{7,}$ T_{10} and T_{11} treatments. WPR (T_2 treatment) provided 3.41% increased yield over sole wheat (T_1 treatment) probably due to wider spacing plants captured more sunlight for photosynthesis. Little (1987) showed that paired row technique increased yields of winter wheat by 13% and of winter barley by 9%.

The pure stands of wheat gave higher grain yield than other wheat yields under intercropping situation. The yield of wheat as sole reduced by 2.84 % to 39.39 % when the crop shared growing condition with grasspea / lentil. Wheat yield was reduced maximum (27.21 % to 39.39 %) when wheat and grasspea / lentil were sown at 1:1 ratio and wheat paired rows accommodated 2 rows of grasspea / lentil. The wheat yield reduction was probably due to interplant competition with grasspea / lentil.

Carr *et al.* (1995) also found that grain yield of wheat was unaffected by intercropping with lentil.

Ahmad *et al.* (1995) demonestred a field experiment where wheat and lentil were grown alone or intercropped in 80 cm x 100 cm strips or wheat: lentil row ratios of 4:3, 5:3, 8:3 or 10:3. Wheat grain yield (4040 kg ha^{-1}) was highest with the 10:3 intercrop. The 8:3 row ratio intercrop produced wheat grain yield of 3760 kg ha^{-1}.

4.1.3 Harvest Index (%)

Harvest Index of wheat was varied significantly due to different sowing patterns along with grasspea / lentil (Table 5). The highest (42.40%) harvest Index was obtained from T_{13} (Wheat + lentil (3:1) + 120kg N ha^{-1}) treatment. The lowest (38.35%) harvest Index was obtained from T_8 (WPR + 1 row lentil + 80kg N ha^{-1}) treatment.

Table 5: Weight of 1000 grains, Grain yield and harvest Index of wheat as influenced by different intercropping systems with grasspea / lentil

Treatments	Weight of 1000 grains	Grain yield (t ha^{-1})	Harvest Index (%)
T_1	40.40	3.22	41.09
T_2	39.98	3.41	40.28
T_5	41.00	2.34	38.68
T_6	40.28	2.75	40.05
T_7	40.05	2.32	38.50
T_8	41.58	2.31	38.35
T_9	39.50	2.72	41.40
T_{10}	41.60	2.49	39.90
T_{11}	42.40	2.53	41.05
T_{12}	41.35	2.93	41.35
T_{13}	40.68	2.95	42.40
T_{14}	41.32	2.93	41.32
$LSD_{(0.05)}$	1.594	0.393	1.251
CV (%)	2.30	8.44	1.83

T_1 = Wheat normal row + 100kg N ha^{-1}
T_2 = Wheat paired row (WPR) + 100kg N ha^{-1}
T_5 = WPR + 1 row grasspea + 80kg N ha^{-1}
T_6 = WPR + 1 row grasspea + 100kg N ha^{-1}
T_7 = WPR + 1 rows grasspea + 120kg N ha^{-1}
T_8 = WPR + 1 row lentil + 80kg N ha^{-1}
T_9 = WPR + 1 row lentil + 100kg N ha^{-1}
T_{10} = WPR +1 row lentil + 120kg N ha^{-1}
T_{11} = Wheat + lentil (3:1) + 80kg N ha^{-1}
T_{12} = Wheat + lentil (3:1) + 100kg N ha^{-1}
T_{13}= Wheat + lentil (3:1) + 120kg N ha^{-1}
T_{14}= Wheat + grass pea (3:1) +100kg N ha^{-1}

4.2 Grasspea

4.2.1 Growth attributes of grasspea

4.2.1.1 Plant height (cm)

Plant height of grasspea was significantly affected by different intercropping systems. Plant height increased with the advancement of crop age (Fig. 2). At 20 DAS, tallest plant (10.91 cm) was obtained from T_6 treatment and it was statistically similar with T_7 treatment. The shortest plant (9.80cm) was obtained from T_{14} treatment which was statistically similar with T_3 and T_5 treatments. At 40 DAS, highest plant height (17.67 cm) was obtained from T_7 treatment (Wheat paired row (WPR) + 1 row grasspea + 120kg N ha^{-1}) which was statistically similar with T_3 treatment and the lowest (14.23 cm) from T_5 treatment) which was statistically similar with T_6 treatment.

At 60 DAS, tallest plant (30.15 cm) was recorded with T_7 treatment (Wheat paired row (WPR) + 1 row grasspea + 120kg N ha^{-1}). The shortest plant (21.79 cm) was recorded with T_5 treatment (WPR + 2 rows grasspea) treatment. At 60 DAS, maximum plant height (30.75 cm) was obtained from T_7 treatment (Wheat paired row (WPR) + 1 row grasspea + 120kg N ha^{-1}) and the minimum plant height (21.79 cm) was obtained from T_5 treatment. At 80 DAS, the highest plant height (56.70 cm) was obtained from T_6 treatment where as lowest plant height (40.14 cm) was obtained from T_5 treatment which was statistically similar with T_3 treatment.

At 100 DAS, 57.63 cm plant height was obtained from T_7 treatment (Wheat paired row (WPR) + 1 row grasspea + 120kg N ha^{-1}) which was highest while the lowest plant height (50.00 cm) was obtained from T_{14} treatment (Wheat + grasspea (3:1) +100kg N ha^{-1}). At maturity, the tallest plant (56.12 cm) was obtained from T_3 treatment which was statistically similar with $T_{5,}$ and T_7 treatments whereas the shortest plant (51.09 cm) was obtained from T_{14} treatment which was statistically similar with T_5 treatment. The results revealed that in maximum cases sole grasspea showed shortest plant and the tallest plant was found in intercropped grasspea.

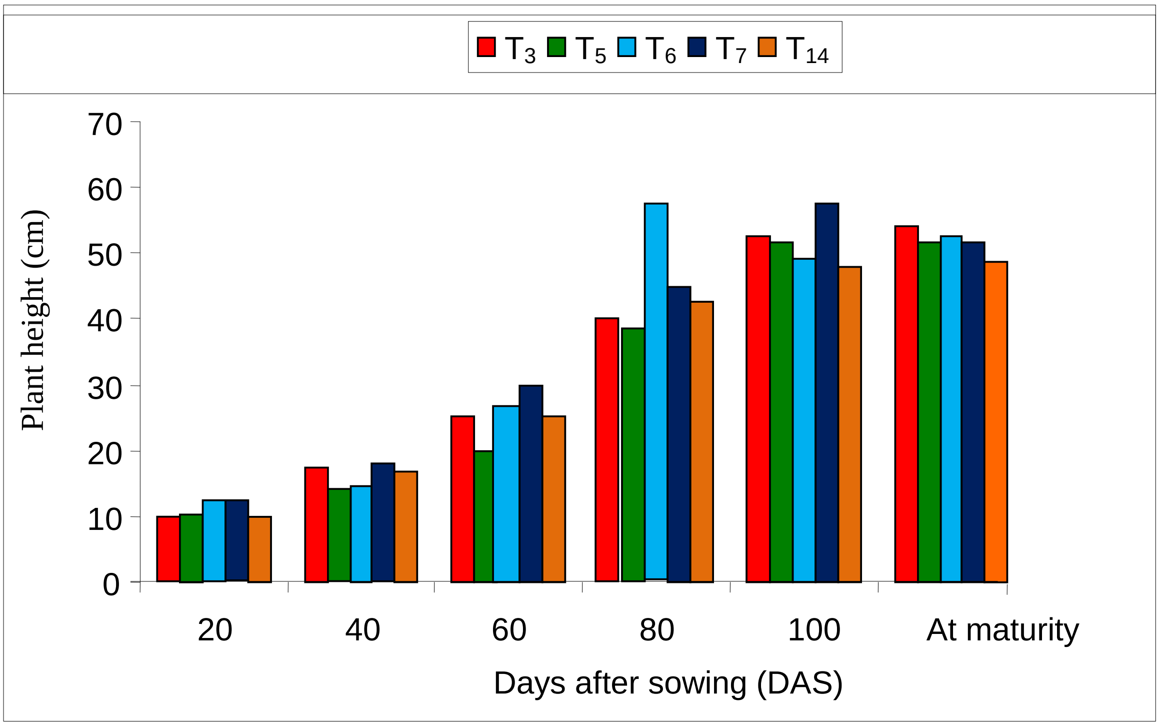

Fig.2. Plant height (cm) of grasspea at different days as affected by different intercropping systems with wheat ($LSD_{(0.05)}$ = 0.58, 1.11, 2.00, 4.39, 1.67 and 3.24 at 20, 40, 60, 80, 100 DAS and harvest, respectively)

T_3 = Sole grasspea + 20kg N ha^{-1}

T_5 = Wheat paired row (WPR) + 1 row grasspea + 80kg N ha^{-1}

T_6 = Wheat paired row (WPR) + 1 row grasspea + 100kg N ha^{-1}

T_7 = Wheat paired row (WPR) + 1 row grasspea + 120kg N ha^{-1}

T_{14}= Wheat + grasspea (3:1) +100kg N ha^{-1}

4.2.1.2 Above ground dry matter plant^{-1} (g)

above ground dry matter plant^{-1} of grasspea was affected significantly by different intercropping systems (Table 6). At 20, 40, 60, and 100 DAS, maximum dry matter of grasspea was found in sole grasspea and the lowest was found in intercropped grasspea at 20, 40, 60, 80 and 100 DAS. At maturity, the maximum dry matter was found in sole grasspea and the lowest from intercropped grasspea. Similar findings were also found by Singh (1979) and Singh (1983). They reported that the highest dry matter of grasspea might be attributed to favorable growth attributes as there was no competition in sole cropping.

Table 6: Above ground dry matter (g plant^{-1}) of grasspea at different days as affected by different intercropping systems with wheat

Treatments	DAS					**At harvest**
	20	40	60	80	100	
T_3	0.05	0.41	0.91	2.29	8.33	7.98
T_5	0.04	0.20	0.53	1.57	3.90	3.75
T_6	0.05	0.20	0.41	2.49	5.20	5.01
T_7	0.04	0.29	0.50	1.97	5.00	4.67
T_{14}	0.04	0.23	0.53	1.64	5.40	5.03
$LSD_{(0.05)}$	0.008	0.032	0.119	0.376	0.947	0.519
CV (%)	10.16	5.42	10.35	10.06	9.03	5.22

T_3 = Sole grasspea + 20kg N ha^{-1}

T_5 = Wheat paired row (WPR) + 1 row grasspea + 80kg N ha^{-1}

T_6 = Wheat paired row (WPR) + 1 row grasspea + 100kg N ha^{-1}

T_7 = Wheat paired row (WPR) + 1 row grasspea + 120kg N ha^{-1}

T_{14}= Wheat + grasspea (3:1) +100kg N ha^{-1}

4.2.1.3 Branches plant^{-1}

Branches plant^{-1} of grasspea was affected significantly by different intercropping systems (Table 7). At 60, 80, 100 DAS and maturity maximum number of branches of grasspea was recorded in T_3 treatment (sole grasspea). The lowest number of branches plant^{-1} was 4.72, 7.67, 8.82, 10.01, and 10.61 recorded from $T_{5,}$ $T_{14,}$ $T_{5,}$ T_5 and T_5 treatments at 40, 60, 80, 100 DAS and maturity, respectively.

From the above it was found that sole grasspea gave maximum number of branches and intercropped grasspea gave the lowest. This might be probability of intercropping interferes in the branch formation of grasspea due to more competition with wheat.

Table 7: Branches plant^{-1} (no) of grasspea at different days as affected by different intercropping systems with wheat

Treatments	DAS				At harvest
	40	60	80	100	
T_3	4.96	12.65	15.47	16.40	16.65
T_5	4.72	7.76	8.82	10.01	10.61
T_6	5.02	8.80	9.27	10.60	12.40
T_7	5.22	9.00	10.77	11.78	14.00
T_{14}	4.86	7.67	9.46	11.13	11.26
LSD$_{(0.05)}$	0.315	0.654	0.412	0.757	1.128
CV (%)	9.42	3.79	2.03	3.36	4.61

T_3 = Sole grasspea + 20kg N ha^{-1}
T_5 = Wheat paired row (WPR) + 1 row grasspea + 80kg N ha^{-1}
T_6 = Wheat paired row (WPR) + 1 row grasspea + 100kg N ha^{-1}
T_7 = Wheat paired row (WPR) + 1 row grasspea + 120kg N ha^{-1}
T_{14}= Wheat + grasspea (3:1) +100kg N ha^{-1}

4.2.2 Yield and yield attributes

4.2.2.1 Pods plant^{-1}

Number of pods plant^{-1} of grasspea was significantly affected by different intercropping systems (Table 8). The highest (25.20) number of pods plant^{-1} of grasspea was obtained from T_3 treatment (sole grasspea). Due to maximum competition with wheat the lowest (14.60) number of pods plant^{-1} of grasspea was obtained from T_{14} treatment (3: 1 row ratio of wheat and grasspea +100kg N ha^{-1}).

4.2.2.2 Thousand seed weight (g)

Thousand seed weight of grasspea was significantly affected by different intercropping systems. Highest seed weight (54.23 g) was found in T_{14} treatment (Wheat + grasspea (3:1) +100kg N ha^{-1}) which was statistically similar with T_6 treatment and the lowest from T_3 treatment (T_3 = Sole grasspea + 20kg N ha^{-1}) which was statistically similar with T_5 and T_7 treatments.

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

Seed yield of grasspea varied significantly due to different intercropping systems (Table 8). The highest seed yield (1.21 t ha^{-1}) was obtained from T_3 treatment (sole grasspea) and the lowest (0.18 t ha^{-1}) from T_{14} treatment (Wheat + grasspea (3:1) +100kg N ha^{-1}) which was statistically similar with T_5 treatment. Probably lower population of grasspea and maximum competition with wheat on unit area of land cause lower yield. Sole grasspea gave seed yield of 1.21 t ha^{-1} where its yield was reduced by 43.81% to 78.48% under different intercropping systems with wheat.

4.2.3 Harvest Index (%)

Harvest Index of grasspea varied significantly due to different intercropping systems (Table 8). The maximum harvest index (45.84%) was shown on T_3 treatment (sole grasspea) while the minimum harvest index (33.34%) was shown on T_{14} treatment.

Table 8: Yield attributes, yield and harvest index of grasspea as influenced by different intercropping systems

Treatments	Pods plant^{-1} (No.)	1000 seed weight (g)	Seed yield (t ha^{-1})	Harvest Index (%)
T_3	25.20	50.82	1.21	45.84
T_5	24.20	50.96	0.32	39.17
T_6	23.00	52.37	0.46	44.47
T_7	16.53	51.21	0.40	42.00
T_{14}	14.60	54.23	0.18	33.34
$LSD_{(0.05)}$	1.851	2.397	0.178	3.442
CV (%)	4.75	2.45	8.43	4.46

T_3 = Sole grasspea + 20kg N ha^{-1}

T_5 = Wheat paired row (WPR) + 1 row grasspea + 80kg N ha^{-1}

T_6 = Wheat paired row (WPR) + 1 row grasspea + 100kg N ha^{-1}

T_7 = Wheat paired row (WPR) + 1 row grasspea + 120kg N ha^{-1}

T_{14}= Wheat + grasspea (3:1) +100kg N ha^{-1}

4.3 Lentil

4.3.1 Growth attributes of lentil

4.3.1.1 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 DAS, 6.83 cm plant height was obtained from T_{10} treatment (WPR + 1 rows lentil + 120kg N ha^{-1}) which was statistically similar with T_{12} and T_{13} treatments which was highest whereas the lowest plant height (5.50 cm) was obtained from T_9 treatment (WPR + 1 row lentil + 100kg N ha^{-1}) and it was statistically similar with $T_{4,}$ $T_{8,}$ T_{11} and T_{13} treatments. At 40 DAS, tallest plant (13.62 cm) was obtained from T_{13}treatment (Wheat + lentil (3:1) + 120kgN ha^{-1}) and it was statistically similar with $T_{4,}$ $T_{8,}$ $T_{10,}$ and T_{12} treatments. The shortest plant (11.87 cm) was obtained from T_{11} treatment followed by T_9 treatment.

At 60 DAS, highest plant height (22.50 cm) was obtained from T_8 treatment (WPR + 1 row lentil + 80kg N ha^{-1}) which was statistically similar with $T_{10,}$ T_{11} and T_{12} treatments. The lowest plant height (17.60 cm) was obtained from T_4 treatment. At 80 DAS, maximum plant height was 35.53 cm was recorded from T_{11} treatment (Wheat + lentil (3:1) + 80kg N ha^{-1}) which was statistically similar with T_{12} treatment and the minimum plant height 26.80 cm was obtained from T_4 treatment.

At 100 DAS, 39.40 cm plant height was obtained from T_{13} treatment (Wheat + lentil (3:1) + 120kg N ha^{-1}) which was highest and was statistically similar with T_{11} treatment and the lowest (31.80 cm) from T_4 treatment . At maturity, the highest plant height (38.95 cm) was obtained from T_{11} treatment (WPR + 1 row lentil + 120kg N ha^{-1}) which was statistically similar with T_{12} treatment whereas the lowest plant height (33.07 cm) was obtained from T_7 treatment (WPR + 1 row lentil) which was statistically similar with T_8 treatment.

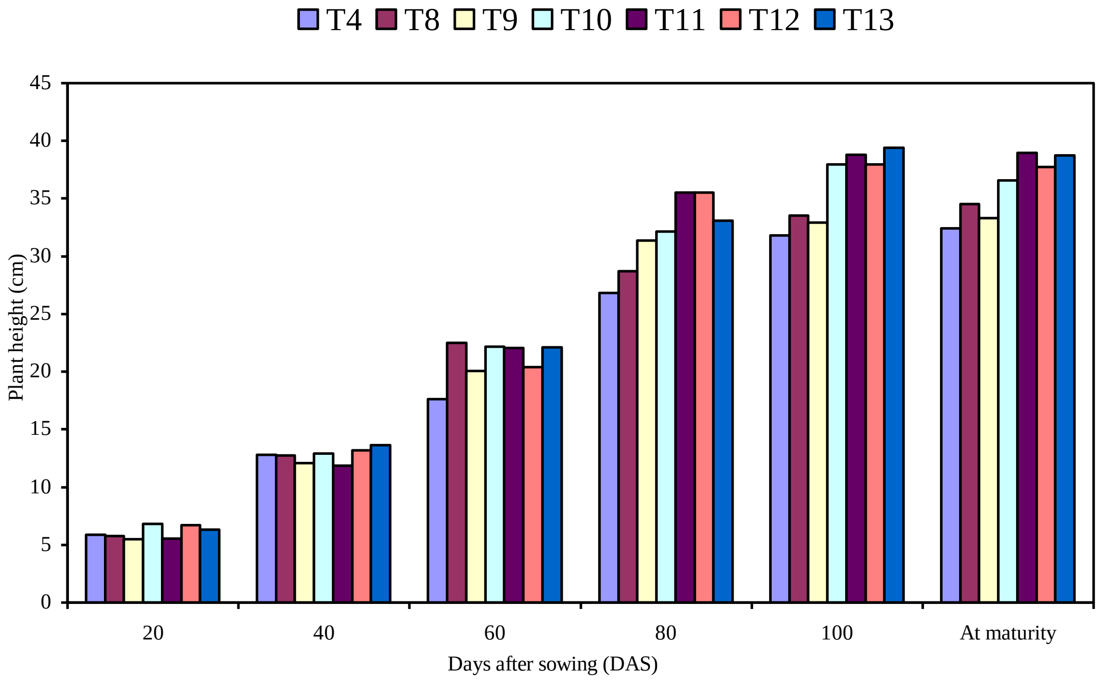

Fig. 3. Plant height (cm) of lentil at different days as affected by different intercropping systems with wheat (LSD$_{(0.05)}$ = 0.92, 1.21, 1.61, 1.34, 1.19, and 1.13 at 20, 40, 60, 80, 100 DAS and maturity, respectively)

T_4 = Sole lentil +20kg N ha^{-1}

T_8 = WPR + 1 row lentil + 80kg N ha^{-1} T_{11} = Wheat + lentil (3:1) + 80kg N ha^{-1}

T_9 = WPR + 1 row lentil + 100kg N ha^{-1} T_{12} = Wheat + lentil (3:1) + 100kg N ha^{-1}

T_{10} = WPR + 1 rows lentil + 120kg N ha^{-1} T_{13}= Wheat + lentil (3:1) + 120kgN ha^{-1}

4.3.1.2 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 (0.05 g) dry matter plant^{-1} of lentil was obtained from T_{13} treatment and lowest (0.03 g) from T_{12} treatment. At 40 DAS, highest dry matter plant^{-1} of lentil (0.38 g) was obtained from T_3 treatment where the lowest dry matter plant^{-1} of lentil (0.15 g) was obtained from T_9 and T_{12} and treatments.

At 60, 80, 100 DAS and at maturity, the maximum dry matter plant^{-1} of lentil was obtained from T_4 treatment (sole lentil). The lowest dry matter plant^{-1} was 0.25, 1.10, 2.07, 1.49 and 2.68 g was obtained from $T_{8,}$ $T_{13,}$ $T_{13,}$ and T_{13} treatments.

Table 9: Above ground dry matter (g plant^{-1}) of lentil at different days as affected by different intercropping systems with wheat

Treatments	DAS					At harvest
	20	40	60	80	100	
T_4	0.04	0.38	0.57	1.87	4.70	5.05
T_8	0.04	0.18	0.25	1.90	3.93	4.16
T_9	0.05	0.15	0.34	1.22	4.64	4.78
T_{10}	0.04	0.16	0.50	1.41	3.54	3.85
T_{11}	0.04	0.16	0.35	1.67	3.03	3.03
T_{12}	0.03	0.15	0.47	1.62	4.60	4.60
T_{13}	0.05	0.16	0.39	1.10	2.07	2.07
$LSD_{(0.05)}$	0.018	0.080	0.113	0.239	0.333	0.298
CV (%)	8.68	7.39	4.94	8.73	4.97	4.23

T_4 = Sole lentil +20kg N ha^{-1}
T_8 = WPR + 1 row lentil + 80kg N ha^{-1}
T_9 = WPR + 1 row lentil + 100kg N ha^{-1}
T_{10} = WPR + 1 rows lentil + 120kg N ha^{-1}
T_{11} = Wheat + lentil (3:1) + 80kg N ha^{-1}
T_{12} = Wheat + lentil (3:1) + 100kg N ha^{-1}
T_{13}= Wheat + lentil (3:1) + 120kgN ha^{-1}

4.3.1.3 Branches plant^{-1}

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 (6.60) was obtained from T_4 treatment which was statistically similar with T_{10} treatment where as the lowest number of branches plant^{-1} (4.49) was obtained from T_{13} treatment.

At 60, 80, 100 DAS and at maturity maximum number of branches plant^{-1} of lentil was obtained from T_4 treatment (sole lentil). At 60, 80, 100 DAS and at maturity the lowest branches plant^{-1} was recorded from T_8 and T_9 treatments.

Table 10: Branches plant^{-1} (no.) of lentil at different days as affected by different intercropping systems with wheat

Treatments	DAS				At harvest
	40	60	80	100	
T_4	6.60	13.93	18.67	26.00	35.24
T_8	4.82	8.42	11.36	14.76	21.80
T_9	5.20	9.53	12.93	15.80	22.70
T_{10}	6.56	10.53	14.89	18.67	26.78
T_{11}	4.80	10.87	13.87	16.40	17.32
T_{12}	4.97	11.76	14.67	17.44	17.60
T_{13}	4.49	12.47	14.80	18.80	18.54
$LSD_{(0.05)}$	0.245	1.746	1.366	1.691	1.930
CV (%)	2.58	8.86	5.31	5.20	4.75

T_4 = Sole lentil +20kg N ha^{-1}

T_8 = WPR + 1 row lentil + 80kg N ha^{-1} T_{11} = Wheat + lentil (3:1) + 80kg N ha^{-1}

T_9 = WPR + 1 row lentil + 100kg N ha^{-1} T_{12} = Wheat + lentil (3:1) + 100kg N ha^{-1}

T_{10} = WPR + 1 rows lentil + 120kg N ha^{-1} T_{13}= Wheat + lentil (3:1) + 120kgN ha^{-1}

4.3.2 Yield and yield attributes

4.3.2.1 Pods plant^{-1}

Pods plant^{-1} was affected significantly by different intercropping systems (Table 11). The highest number of pods plant^{-1} of lentil (92.26) was obtained from T_4 treatment (sole lentil). The lowest number of pods plant^{-1} of lentil (45.02g) was obtained from T_{13} treatment (Wheat + lentil (3:1) + 120kg N ha^{-1}).

4.3.2.2 Thousand seed weight (g)

The maximum seed weight (19.42 g) was found with T_8 treatment (WPR + 1 row lentil + 80kg N ha^{-1}) which was statistically similar with T_4, T_9, T_{10}, T_{11} and T_{13} treatments where as the lowest thousand seed weight (18.40 g) was found from T_{12} treatment (Wheat + lentil (3:1) + 100kg N ha^{-1}) (Table 11).

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

Seed yield of lentil varied significantly due to different intercropping systems (Table 11). The highest (0.75 t ha^{-1}) from T_4 treatment (sole lentil) and the lowest seed yield (0.08 t ha^{-1}) was obtained from T_{13} treatment (Wheat + lentil (3:1) + 120kg N ha^{-1}) which was statistically similar with T_{11} and T_{12} treatments. Probably lower population of lentil on unit area of land causes lower yield. Sole lentil gave seed yield 0.75 t ha^{-1} where its yield was reduced by 70 % to 89 % under different intercropping systems with wheat.

4.3.3 Harvest Index (%)

Harvest Index of lentil varied significantly due to different intercropping systems (Table 11). It was appeared that the sole lentil crop showed maximum value of harvest index that reflected due to higher pods plant^{-1} which increases total number of seeds, thus elevated the seed yield.

Table 11: Yield attributes, yield and harvest index of lentil as influenced by different intercropping systems with wheat

Treatments	No. of pods $plant^{-1}$	1000 seed weight (g)	Seed yield ($t\ ha^{-1}$)	Harvest Index (%)
T_4	92.26	18.86	0.75	40.30
T_8	56.13	19.42	0.18	35.03
T_9	59.00	19.40	0.19	35.60
T_{10}	52.73	19.24	0.18	34.63
T_{11}	54.33	18.90	0.11	28.24
T_{12}	48.73	18.40	0.09	29.01
T_{13}	45.02	18.69	0.08	24.65
$LSD_{(0.05)}$	1.332	0.838	0.056	3.170
CV (%)	1.28	3.42	10.63	5.51

T_4 = Sole lentil +20kg N ha^{-1}

T_8 = WPR + 1 row lentil + 80kg N ha^{-1} T_{11} = Wheat + lentil (3:1) + 80kg N ha^{-1}

T_9 = WPR + 1 row lentil + 100kg N ha^{-1} T_{12} = Wheat + lentil (3:1) + 100kg N ha^{-1}

T_{10} = WPR + 1 rows lentil + 120kg N ha^{-1} T_{13}= Wheat + lentil (3:1) + 120kgN ha^{-1}

4.4 Productivity performance

4.4.1 Relative yield

4.4.1.1 Relative yield of wheat

The relative yield of wheat varied due to different intercropping systems (Table 12). The maximum relative yield of wheat (0.92) was obtained from T_{13} treatment, which was statistically similar with T_{12} and T_{14} treatments, but the lowest relative yield of wheat (0.72) was obtained from T_7 and $T_{8,}$ which was statistically similar with T_5 treatment.

4.4.1.2 Relative yield of grasspea

The maximum relative yield of grasspea (0.38) was obtained from T_6 treatment and the lowest (0.15) from T_{14} treatment (Table 12).

4.4.1.3 Relative yield of lentil

The maximum relative yield of lentil (0.25) was obtained from T_9 treatment where as the lowest relative yield of lentil (0.11) was obtained from T_{13} treatment (Table 12).

4.5 Combined yield of wheat and grasspea / lentil

Combined yield obtained in intercropping systems were always higher than those obtained in sole cropping (Table 12). This increased combined yield may be due to better utilization of space, soil nutrient and moisture by both the crops. The highest combined yield (3.41 t ha^{-1}) was found in T_2 treatment and the lowest (0.75 t ha^{-1}) in T_4 treatment. The second and third highest combined yield 3.22 and 3.21 t ha^{-1} was found in T_1 and T_6 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. Bora (1999) conducted an experiment and showed that wheat + rapeseed were the best combination for obtaining the maximum yield at 1:1 row ratio over 1:2, 1:3, 3:1 and 2:1 row ratios.

4.6 Land Equivalent Ratio (LER)

Intercropping offered significant effect on land equivalent ratio under different intercropping systems (Table 12). The highest LER value (1.23) was obtained from combined yield treatment (T_6). The LER value of 1.23 means that by intercropping 2.75 t of wheat and 0.46 t of grasspea were produced from 1 ha of land instead of growing them separately in 1.23 ha of land. The second highest LER value 1.09 was obtained from T_9 treatment. The lowest LER value 0.94 was obtained from T_{11} treatment which was statistically similar to T_8 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 12: Productivity performance of wheat as sole and grown along with grasspea and lentil under different intercropping systems

Treatments	Relative yield of wheat	Relative yield of grasspea	Relative yield of lentil	Combined yield (t ha^{-1})	LER
T_1	1.00	-	-	3.22	1.00
T_2	1.06	-	-	3.41 (+5.90)	1.06
T_3	-	1.00	-	1.21 (-62.42)	1.00
T_4	-	-	1.00	0.75 (-76.70)	1.00
T_5	0.73	0.26	-	2.66 (-17.39)	0.99
T_6	0.85	0.38	-	3.21 (-0.31)	1.23
T_7	0.72	0.33	-	2.72 (-15.53)	1.05
T_8	0.72	-	0.24	2.49 (-22.67)	0.96
T_9	0.84	-	0.25	2.91 (-9.63)	1.09
T_{10}	0.77	-	0.24	2.67 (-17.10)	1.01
T_{11}	0.79	-	0.15	2.64 (-18.01)	0.94
T_{12}	0.91	-	0.12	3.02 (-6.21)	1.03
T_{13}	0.92	-	0.11	3.03 (-5.90)	1.03
T_{14}	0.91	0.15	-	3.11 (-3.42)	1.06

T_1 = Wheat normal row + 100kg N ha^{-1}
T_2 = Wheat paired row (WPR) + 100kg N ha^{-1}
T_3 = Sole grasspea+20kg N ha^{-1}
T_4 = Sole lentil + 20kg N ha^{-1}
T_5 = WPR + 1 row grasspea + 80kg N ha^{-1}
T_6 = WPR + 1 row grasspea + 100kg N ha^{-1}
T_7 = WPR + 1 rows grasspea + 120kg N ha^{-1}
T_8 = WPR + 1 row lentil + 80kg N ha^{-1}
T_9 = WPR + 1 row lentil + 100kg N ha^{-1}
T_{10} = WPR + 1 row lentil + 120kg N ha^{-1}
T_{11} = Wheat + lentil (3:1) + 80kg N ha^{-1}
T_{12} = Wheat + lentil (3:1) + 100kg N ha^{-1}
T_{13}= Wheat + lentil (3:1) + 120kg N ha^{-1}
T_{14}= Wheat + grasspea (3:1) +100kg N ha^{-1}

4.7 Equivalent yield

4.7.1 Wheat equivalent yield (WEY)

Equivalent yield of wheat was significantly affected by different intercropping systems (Table 13). The maximum wheat equivalent yield 3.90 t ha^{-1} was obtained from T_6 treatment. The lowest wheat equivalent yield 3.03 t ha^{-1} was obtained from T_{11} treatment. Sarno *et al.* (1998) stated that higher equivalent yields were obtained with intercropping. Kulmi and Soni (1997) conducted a field experiment on wheat + sunflower intercropping under 2:1, 2:2, 4:1 or 2:2 row ratios. They found that wheat equivalent yield was highest (3.29 t ha^{-1}) when wheat and sunflower were intercropped in 4:1 row ratios. This treatment also gave the highest net profit and land equivalent ratio (1.15).

Singh and Katyal (1996) conducted an experiment where wheat and lentil were grown alone or intercropped in 1:1, 1:2, 2:1 or 2:2 row ratios and found that wheat and lentil yields were highest in their sole crops. However, wheat productivity was higher when intercropped then when grown alone. Wheat equivalent yield was highest when lentil was grown as a sole crop due to its high sale price.

4.7.2 Grasspea equivalent yield (GEY)

Equivalent yield of grasspea was significantly affected by different intercropping systems (Table 13). Maximum grasspea equivalent yield 1.56 t ha^{-1} was obtained from T_6 treatment. The lowest grasspea equivalent yield 1.21 t ha^{-1} was obtained from T_3 treatment.

4.7.3 Lentil equivalent yield (LEY)

Equivalent yield of lentil was significantly affected by different intercropping systems (Table 13). Maximum lentil equivalent yield 0.79 t ha^{-1} was obtained from T_9 treatment. The lowest lentil equivalent yield 0.67 t ha^{-1} was obtained from T_{11} treatment.

Table 13: Equivalent yields of wheat, grasspea and lentil as affected by different intercropping systems

Treatments	Wheat equivalent yield (t ha^{-1})	Grasspea equivalent yield (t ha^{-1})	Lentil equivalent yield (t ha^{-1})
T_1	3.22	-	-
T_2	3.41	-	-
T_3	-	1.21	-
T_4	-	-	0.75
T_5	3.14	1.26	-
T_6	3.90	1.56	-
T_7	3.32	1.33	-
T_8	3.12	-	0.69
T_9	3.58	-	0.79
T_{10}	3.30	-	0.73
T_{11}	3.03	-	0.67
T_{12}	3.34	-	0.74
T_{13}	3.31	-	0.74
T_{14}	3.38	1.25	-

T_1 = Wheat normal row + 100kg N ha^{-1}
T_2 = Wheat paired row (WPR) + 100kg N ha^{-1}
T_3 = Sole grasspea+20kg N ha^{-1}
T_4 = Sole lentil + 20kg N ha^{-1}
T_5 = WPR + 1 row grasspea + 80kg N ha^{-1}
T_6 = WPR + 1 row grasspea + 100kg N ha^{-1}
T_7 = WPR + 1 rows grasspea + 120kg N ha^{-1}
T_8 = WPR + 1 row lentil + 80kg N ha^{-1}
T_9 = WPR + 1 row lentil + 100kg N ha^{-1}
T_{10} = WPR + 1 row lentil + 120kg N ha^{-1}
T_{11} = Wheat + lentil (3:1) + 80kg N ha^{-1}
T_{12} = Wheat + lentil (3:1) + 100kg N ha^{-1}
T_{13}= Wheat + lentil (3:1) + 120kg N ha^{-1}
T_{14}= Wheat + grasspea (3:1) +100kg N ha^{-1}

4.8 Economic performance

4.8.1 Total variable cost

Total variable cost was affected by different intercropping systems (Table 14). The highest variable cost Tk. 49126 ha^{-1} was obtained from T_7 (WPR + 1 rows grasspea + 120kg N ha^{-1}) treatment and the lowest Tk.35874 ha^{-1} from T_3 (Sole grasspea+20kg N ha^{-1}) treatment.

4.8.2 Gross return

Gross return was affected by different intercropping systems (Table 14). The highest gross return Tk. 88890 ha^{-1} was obtained from T_6 (WPR + 1 row grasspea + 100kg N ha^{-1}) treatment.The lowest gross return Tk. 64350 ha^{-1} was obtained from T_3 (Sole grasspea+20kg N ha^{-1}) treatment.

Chowdhury *et al.* (2009) Showed that sole pigeonpea 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.

4.8.3 Net return

The highest net return Tk. 40047 ha^{-1} over variable cost was obtained from T_6 (WPR + 1 row grasspea + 100kg N ha^{-1}) treatment (Table 14). The lowest net returns Tk. 23866 ha^{-1} was obtained form T_5 (WPR + 1 row grasspea + 80kg N ha^{-1}) treatment.

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

Monetary advantages were affected by different intercropping systems (Table 14). The highest monetary advantage value of Tk. 16621.70ha^{-1} was obtained from T_6 treatment. The second highest monetary advantage value of Tk. 6746.69 ha^{-1} was obtained from T_9 treatment. The third highest monetary advantage value of Tk. 4340.66 ha^{-1} was obtained from T_{14} treatment. The lowest monetary advantage value Tk. -4429.47 ha^{-1} was obtained from T_{11} treatment which showed negative value.

Maximum monetary advantage was obtained from T_6 treatment (WPR + 1 row grasspea + 100kg N ha^{-1}). Similar results was found by Singh *et al*. (1992) who stated that monetary advantage over sole wheat indicated a positive gain from intercropping systems. Banik (1994) carried out an experiment to evaluate wheat and legume intercropping under 1:1 and 2:1 row ratios and found that wheat-peas intercropping (1:1) gave the highest wheat equivalent yield and highest monetary returns.

4.9 Benefit-cost ratio

Benefit cost ratio was significantly affected by different intercropping system (Table 14). When benefit-cost ratio of each treatment was examined it was found that the treatment T_6 gave the highest benefit cost ratio (1.82).

The cost and return analysis indicated that the treatment of T_6 gave the best combinations in respect of gross return, net return and benefit cost ratio.

Table 14: Economic analysis of wheat and grasspea /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	46666	73245	26579	-	1.57
T_2	47768	77565	29797	-	1.62
T_3	35874	64350	28476	-	1.79
T_4	40543	70725	30182	-	1.74
T_5	47532	71398	23866	-721.19	1.50
T_6	48843	88890	40047	16621.70	1.82
T_7	49126	76572	27446	3646.28	1.56
T_8	47884	72044	24160	-3001.83	1.50
T_9	48035	81710	33675	6746.69	1.70
T_{10}	48302	76305	28003	755.50	1.58
T_{11}	44865	69395	24530	-4429.47	1.55
T_{12}	45125	75692	30567	2204.62	1.68
T_{13}	45328	75100	29772	2187.37	1.66
T_{14}	45225	76685	31460	4340.66	1.70

T_1 = Wheat normal row + 100kg N ha^{-1}
T_2 = Wheat paired row (WPR) + 100kg N ha^{-1}
T_3 = Sole grasspea+20kg N ha^{-1}
T_4 = Sole lentil + 20kg N ha^{-1}
T_5 = WPR + 1 row grasspea + 80kg N ha^{-1}
T_6 = WPR + 1 row grasspea + 100kg N ha^{-1}
T_7 = WPR + 1 rows grasspea + 120kg N ha^{-1}
T_8 = WPR + 1 row lentil + 80kg N ha^{-1}
T_9 = WPR + 1 row lentil + 100kg N ha^{-1}
T_{10} = WPR + 1 row lentil + 120kg N ha^{-1}
T_{11} = Wheat + lentil (3:1) + 80kg N ha^{-1}
T_{12} = Wheat + lentil (3:1) + 100kg N ha^{-1}
T_{13}= Wheat + lentil (3:1) + 120kg N ha^{-1}
T_{14}= Wheat + grasspea (3:1) +100kg Nha^{-1}

Price rate: Wheat seed Tk. 20 kg^{-1} grsspea seed Tk. 50 kg^{-1} and lentil Tk.90 kg^{-1}. Variable cost includes cost of fertilizer irrigation, labor, seeds etc. benefit cost ratio is based on the total variable cost only.

Chapter 5

SUMMARY AND CONCLUSION

The experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka, during the period from 16 November 2009 to 10 March 2010 to study the performance of wheat and grasspea / lentil under intercropping systems. Fourteen treatment combinations were T_1 = Wheat normal row + 100kg N ha^{-1}, T_2 = Wheat paired row (WPR) + 100kg N ha^{-1}, T_3 = Sole grasspea+20kg N ha^{-1}, T_4 = Sole lentil + 20kg N ha^{-1}, T_5 = WPR + 1 row grasspea + 80kg N ha^{-1}, T_6 = WPR + 1 row grasspea + 100kg N ha^{-1}, T_7 = WPR + 1 rows grasspea + 120kg N ha^{-1}, T_8 = WPR + 1 row lentil + 80kg N ha^{-1} T_9 = WPR + 1 row lentil + 100kg N ha^{-1}, T_{10} = WPR + 1 row lentil + 120kg N ha^{-1}, T_{11} = Wheat + lentil (3:1) + 80kg N ha^{-1} , T_{12} = Wheat + lentil (3:1) + 100kg N ha^{-1} T_{13}= Wheat + lentil (3:1) + 120kg N ha^{-1} T_{14}= Wheat + grasspea (3:1) +100kg N ha^{-1}.The experiment was conducted in Randomized Complete Block design with three replications. The experimental materials were wheat (cv. shourav), grasspea (cv. BARI khesari-2) and lentil (cv. BARI moshur-4). The recommended seed rate of wheat, grasspea and lentil was 120, 50 and 35 kg ha^{-1}, respectively. Seeds of these crops were sown on 16 November 2009 and harvested at 10 March 2010. 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 wheat, grasspea and lentil were significant due to intercropping systems. At maturity, the highest plant height (81.85cm) of wheat was obtained from T_{14} treatment and the lowest (75.09cm) was obtained from T_5 treatment. Spike length of wheat at harvest was affected significantly by different intercropping systems. Number of tillers plant^{-1}, number of spikelet spike^{-1} and 1000 grain weight of wheat were also affected significantly by different intercropping systems. The highest number of spikelet spike^{-1} (20.19) was obtained from T_9 treatment and the lowest (15.98) was obtained from T_7 treatment.

Wheat grain yield was affected significantly by different intercropping systems. The highest grain yield (3.41 t ha^{-1}) obtained from T_2 treatment (WPR). Among the intercropping system the highest yield (3.21 t ha^{-1}) obtained from T_6 treatment. On the contrary, the lowest grain yield (2.64 t ha^{-1}) was obtained from T_{11} treatment, which may be due to using lowest nitrogen rate. Plant height, number of branches $plant^{-1}$, dry weight, number of pods $plant^{-1}$ and 1000 seed weight of grasspea and lentil were also affected significantly by different intercropping systems.

The yield of grasspea was also affected significantly by different intercropping systems. The highest seed yield of grasspea (1.21 t ha^{-1}) was obtained from T_3 treatment (sole grasspea), which may be due to higher seed rate and absence of any intra competition with another crop. Among the intercropped treatments, the maximum seed yield of grasspea (0.46 t ha^{-1})was obtained from T_6. The lowest seed yield of grasspea (0.18 t ha^{-1}) was obtained from T_{14} treatment. This might be due to presence of inter competition with another crop.

The yield of lentil also affected significantly by different intercropping systems. The highest seed yield of lentil (0.75 t ha^{-1}) obtained from T_4 treatment (sole lentil) might be due to higher seed rate and absence of any intra competition with another crop. Among the intercropped treatments, T_7 treatment gave the maximum seed yield. The lowest seed yield of lentil (0.08 t ha^{-1}) was obtained from T_{13} treatment. This might be due topresence of inter competition with another crop.

Harvest index of wheat and grasspea / lentil were also affected significantly by different intercropping systems. Maximum harvest index of wheat (42.40%) was obtained from T_{13} treatment and the lowest (38.35%) was obtained from T_8 treatment. Maximum harvest index of grasspea (45.84%) was obtained from T_3 treatment and the lowest (33.34%) was obtained from T_{14} treatment and the maximum harvest index of lentil (40.30%) was obtained from T_4 treatment and the lowest (24.65%) was obtained from T_{13} treatment.

Relative yield of wheat, grasspea and lentil were found to be significantly lower 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 1.23 was obtained from T_6 treatment and the lowest 0.94 was obtained from T_{11} treatment. The highest wheat equivalent yield of 3.90 t ha^{-1} was obtained from T_6

treatment, grasspea equivalent yield of 1.56 t ha^{-1} was obtained from T_6 treatment and the highest lentil equivalent yield of 0.79 t ha^{-1} was obtained from T_9 treatment. On the contrary, the lowest wheat equivalent yield of 3.03 t ha^{-1} was obtained from T_{11} treatment. Grasspea equivalent yield of 1.25 t ha^{-1} was obtained from T_{14} treatment and the lowest lentil equivalent yield of 0.67 t $ha^{-1}$was was obtained from T_{11} treatment.

The highest monetary advantage of Tk. 16621.70 ha^{-1} was obtained from T_6 treatment and the lowest Tk. -721.19 ha^{-1} was obtained from T_5 treatment. Treatment $T_{5,}$ T_8 and T_{11} gave negative value but other treatments showed positive value.

The highest combined yield 3.21 t ha^{-1} was obtained from T_6 treatment and the lowest combined yield 2.64 t $ha^{-1}$was obtained from T_{11} treatment.

The highest gross return of Tk. 88890 ha^{-1} and net return Tk. 40047 ha^{-1} was obtained from T_6 treatment. The highest benefit cost ratio of 1.82 was obtained from T_6 treatment. The lowest benefit cost ratio of 1.50 was obtained from T_5 and T_8 treatment.

The results revealed that was seen T_6 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 grasspea fitted in between two paired rows of wheat under 100kg N ha^{-1} of intercropping system.

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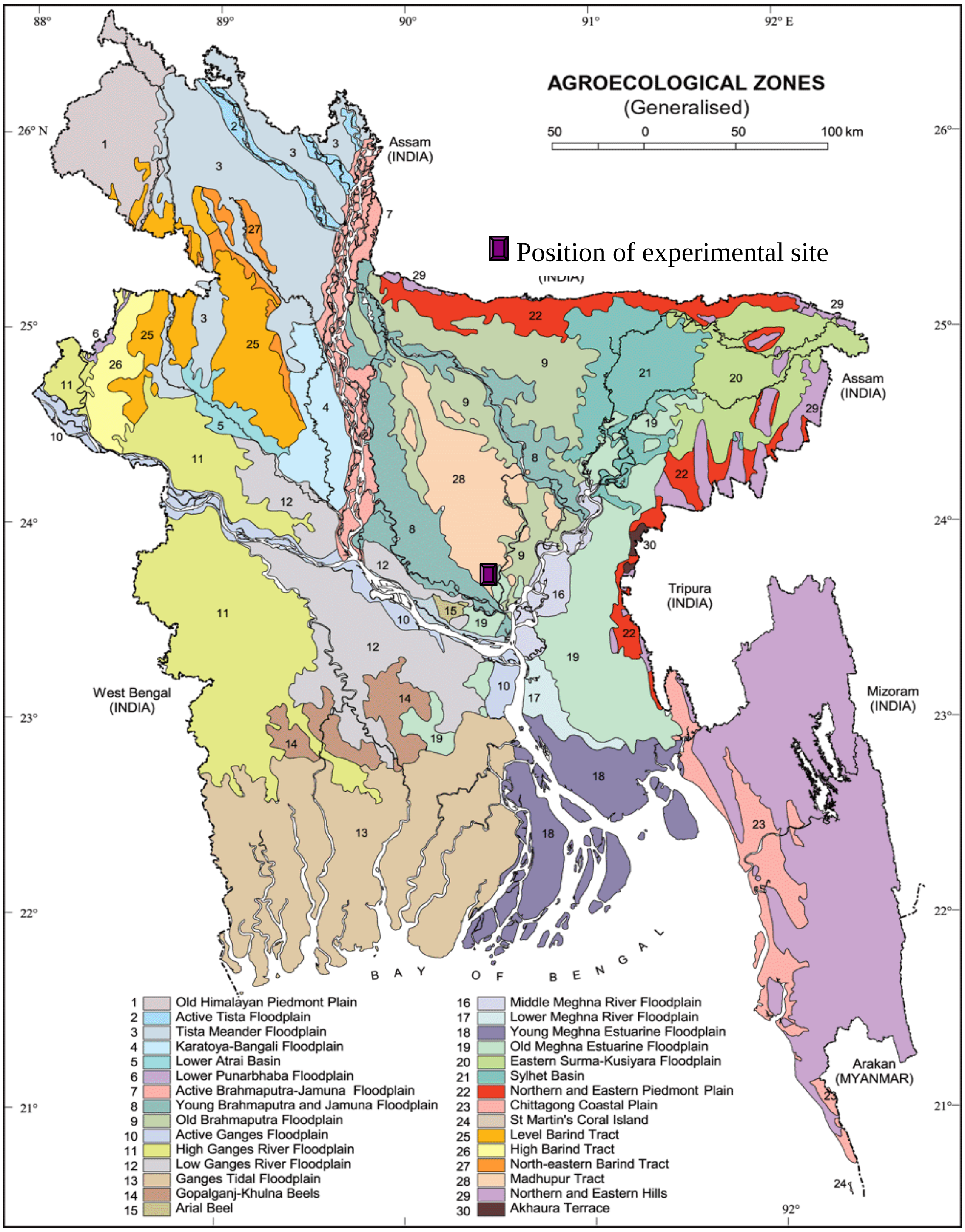
APPENDICES

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 2009-2010

Month	Air temperature (°C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
November	26.98	14.88	71.15	00
December	25.78	14.21	68.30	00
January	25.00	13.46	69.53	00
February	29.50	18.49	50.31	00
March	33.80	20.28	44.95	00

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

Appendix III. Chemical properties of the soil of experiment field before seed sowing

CHARACTERISTICS	VALUE
pH	5.70
Organic matter (%)	2.35
Total N (%)	0.12
K (me/100 g soil)	0.17
P (Mg/g soil)	8.90
S (Mg/g soil)	30.55
B (Mg/g soil)	0.62
Fe (Mg/g soil)	310.40
Zn (Mg/g soil)	4.82

Source: Soil Resource Development Institute (SRDI), Krishi Khamar Sharak, Dhaka

Appendix IV: ANOVA for plant height of wheat

Source of variation	Degrees of Freedom	Error Mean Square					
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	0.128	0.404	3.506	3.273	3.436	1.050
Treatments	11	5.401**	12.845**	29.232**	24.526**	21.842**	16.926**
Error	22	0.321	2.520	2.625	3.791	3.148	2.249
Total	35						

** = Significant at 1% level

Appendix V: ANOVA for dry matter of wheat

Source of variation	Degrees of Freedom	Error Mean Square					
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	0.000	0.008	0.006	0.106	0.268	0.529
Treatments	11	0.001**	0.042**	0.194**	2.021**	1.610**	2.098**
Error	22	0.001	0.001	0.006	0.083	0.204	0.115
Total	35						

** = Significant at 1% level

Appendix VI: ANOVA for number of tillers m^{-2} of wheat

Source of variation	Degrees of Freedom	Error Mean Square				
		40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	3.299	0.542	4.026	2.794	3.159
Treatments	11	257.497**	113.072**	319.740**	264.830**	268.551**
Error	22	4.134	3.615	1.129	3.450	1.384
Total	35					

** = Significant at 1% level

Appendix VII: ANOVA for length of spike of wheat

Source of variation	Degrees of Freedom	Error Mean Square			
		60 DAS	80 DAS	100DAS	At harvest
Replication	2	0.028	0.127	0.280	2.876
Treatments	11	0.941**	0.964**	3.481**	1.429**
Error	22	0.158	0.119	0.215	0.306
Total	35				

** = Significant at 1% level

Appendix VIII: ANOVA for spikelet spike^{-1} of wheat

Source of variation	Degrees of Freedom	Error Mean Square			
		60 DAS	80DAS	100 DAS	At harvest
Replication	2	1.172	0.054	0.072	0.519
Treatments	11	4.927**	7.466**	5.594**	5.438**
Error	22	0.158	0.630	0.253	0.645
Total	35				

** = Significant at 1% level

Appendix IX: ANOVA for 1000 grain weight, grain yield and harvest index of wheat

Source of variation	Degrees of Freedom	Error Mean Square		
		1000 grain wt (g)	Grain yield (t ha^{-1})	Harvest Index (%)
Replication	2	0.669	0.069	0.191
Treatments	11	2.118*	0.388**	5.125**
Error	22	0.886	0.054	0.546
Total	35			

* = Significant at 5% level
** = Significant at 1% level

Appendix X: ANOVA for plant height of grasspea

Source of variation	Degrees of Freedom	Error Mean Square					
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	0.051	0.078	1.258	1.000	12.243	3.070
Treatments	4	0.564**	6.821**	28.541**	132.373**	24.523**	10.758**
Error	8	0.095	0.345	1.123	5.437	0.788	2.967
Total	14						

** = Significant at 1% level

Appendix XI: ANOVA for above ground dry matter of grasspea

Source of variation	Degrees of Freedom	Error Mean Square					
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	0.000	0.001	0.005	0.026	0.308	0.199
Treatments	4	0.001*	0.024**	0.112**	0.479**	8.173 **	7.604**
Error	8	0.00032	0.0003	0.004	0.040	0.253	0.076
Total	14						

* = Significant at 5% level
** = Significant at 1% level

Appendix XII: ANOVA for number of branches plant^{-1} of grasspea

Source of variation	Degrees of Freedom	Error Mean Square				
		40 DAS	60DAS	80 DAS	100 DAS	At harvest
Replication	2	0.230	1.976	1.383	1.407	0.525
Treatments	4	0.104 **	12.386**	22.393**	19.564**	17.566**
Error	8	0.028	0.121	0.048	0.162	0.359
Total	14					

** = Significant at 1% level

Appendix XIII: ANOVA for number of pods plant^{-1}, 1000 seed weight ,seed yield and harvest index of grasspea

Source of variation	Degrees of Freedom	Error Mean Square			
		No. of pods plant^{-1}	1000 seed weight (g)	Seed yield (t ha^{-1})	Harvest Index (%)
Replication	2	0.338	6.751	0.015	0.000
Treatments	4	69.292**	6.131 **	0.487**	73.863**
Error	8	0.966	1.621	0.009	3.341
Total	14				

** = Significant at 1% level

Appendix XIV: ANOVA for plant height of lentil

Source of variation	Degrees of Freedom	Error Mean Square					
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	0.095	0.639	1.682	2.137	0.115	0.119
Treatments	6	0.904*	1.095 **	9.422**	32.057**	30.122**	21.027**
Error	12	0.268	0.464	0.822	0.568	0.448	0.403
Total	20						

* = Significant at 5% level
** = Significant at 1% level

Appendix XV: ANOVA for above ground dry matter of lentil

Source of variation	Degrees of Freedom	Error Mean Square					
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	0.001	0.000	0.000	0.055	0.135	0.229
Treatments	6	0.005 **	0.021**	0.036**	0.287**	2.912**	3.374**
Error	12	0.0001	0.002	0.004	0.018	0.035	0.028
Total	20						

** = Significant at 1% level

Appendix XVI: ANOVA for Number of branches plant^{-1} of lentil

Source of variation	Degrees of Freedom	Error Mean Square				
		40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	0.001	0.157	1.421	0.066	2.820
Treatments	6	2.258**	10.171**	15.184**	41.400**	123.401**
Error	12	0.019	0.963	0.590	0.903	1.177
Total	20					

** = Significant at 1% level

Appendix XVII: ANOVA for number of pods plant $^{-1}$, 1000 seed weight seed yield and harvest index of lentil

Source of variation	Degrees of Freedom	Error Mean Square			
		No. of pods plant^{-1}	1000 seed weight (g)	Seed yield (t ha^{-1})	Harvest Index (%)
Replication	2	6.782	0.675	0.002	0.506
Treatments	6	736.604**	0.439**	0.167**	90.582**
Error	12	0.561	0.222	0.001	3.176
Total	20				

** = Significant at 1% level

PLATES

Plate 1: Field showing normal row planting of wheat at vegetative and grain formation stages

Plate 2: Field showing paired rows planting of wheat at vegetative and grain formation stages

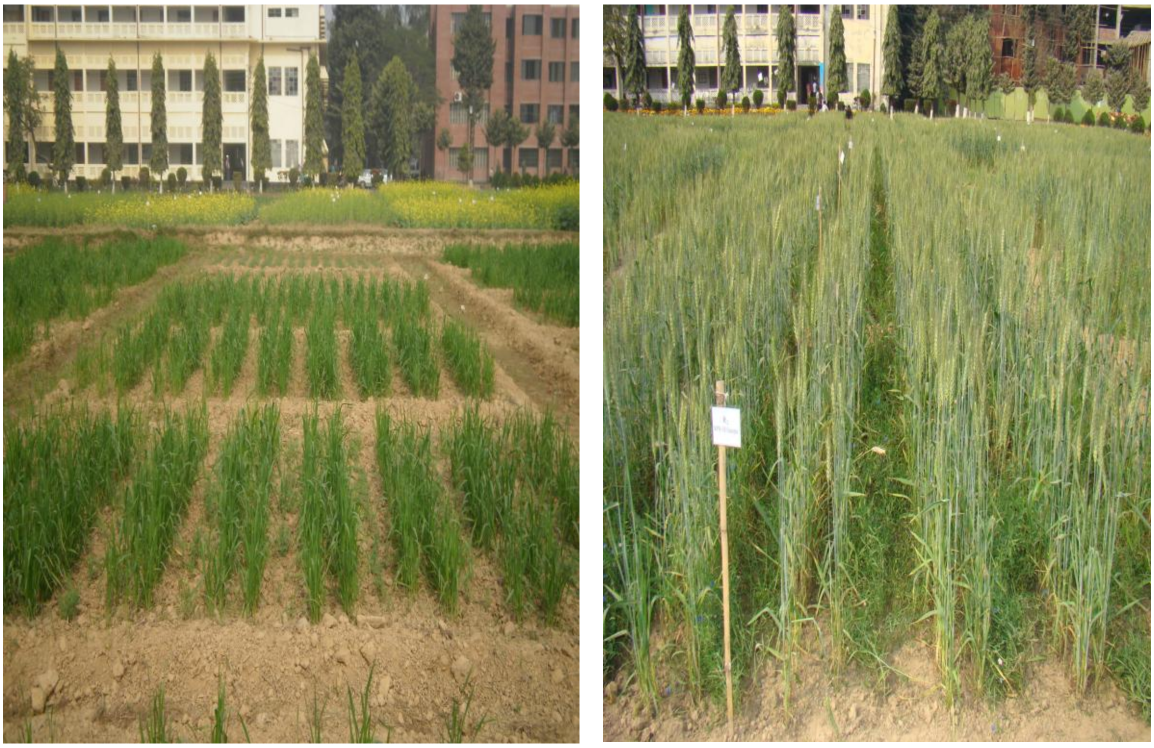


Plate 3: Field showing paired rows of wheat + 1 row grasspea sowing pattern at vegetative and grain formation stages

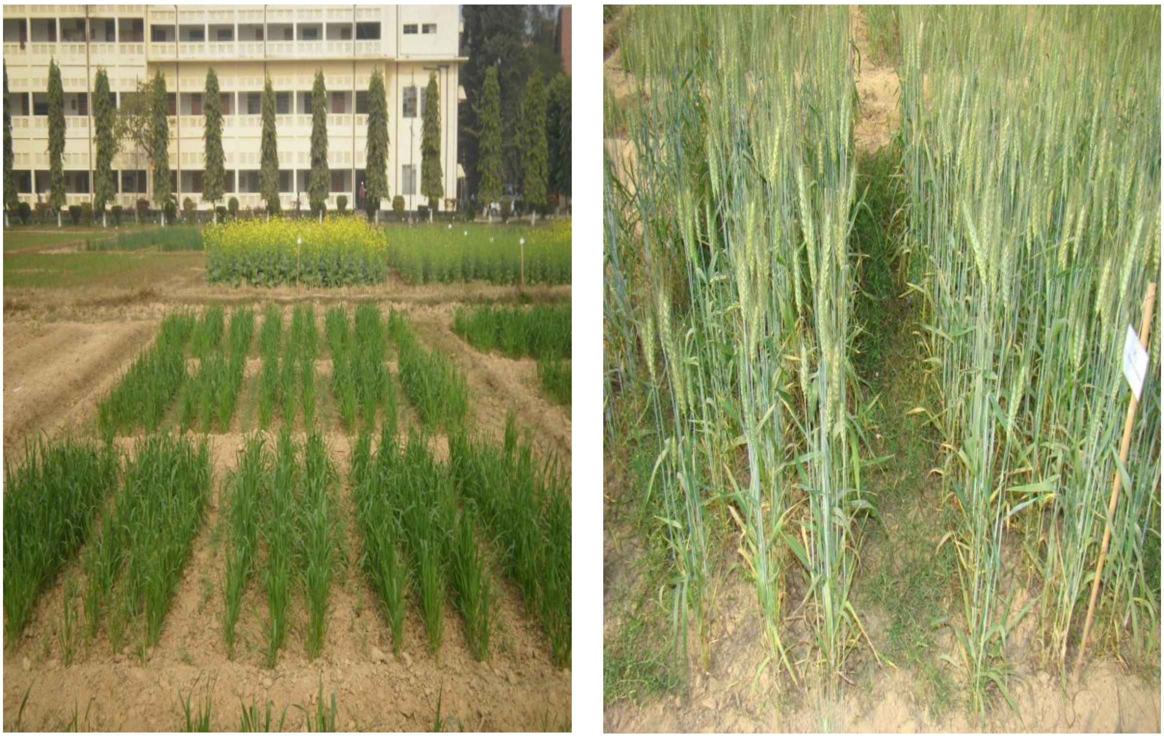


Plate 4: Field showing 3:1 row ratio of wheat & grasspea sowing pattern at vegetative and grain formation stages