Ann. Bangladesh Agric. (2021) 25 (1) : 1-10
www.doi.org/10.3329/aba.v25i1.58150

ISSN 1025-482X (Print)
2521-5477 (Online)

WHEAT–LENTIL MIXED CROPPING SYSTEM PRODUCTIVITY UNDER VARIED IRRIGATION LEVELS

M. G. Neogi[1*], J. C. Biswas[2], M. M. Khan[3] and M. M. Rashid[4]

Abstract

The study on mixed cropping of lentil and wheat was conducted under three levels of irrigation. Wheat at 10, 15, 20, 25, 30, 35, 40, 45 and 50% of the normal seed rates were mixed with full seed rate of lentil to find out a suitable mixing rate of wheat for maximum total yield from unit land. The study was conducted in a split plot design with three replications. Lentil yields obtained with single and two irrigations were identical and higher than with no irrigation. The highest wheat yield was obtained with two irrigations. Total yield was the highest with application of two irrigations. Mixing different proportions of wheat with lentil produced 95-171% additional yield over sole cropping of lentil. Mixing of wheat at 25-35% with lentil was found to be judicious for obtaining maximum total yields. The highest protein yield was obtained with 30-35% and 35% mixing rates of wheat at zero and single irrigation levels. Growing wheat with lentil resulted in increased protein yield in wheat than sole cropping. The highest land equivalent ratio (LER) values were obtained when 30-35% of wheat seed rate were mixed with lentil. Application of two irrigations resulted in high LER values. It is concluded that use of 35% of wheat seed rate along with full seed rate of lentil under two levels of irrigations would be the best mixing ratio for obtaining the highest wheat and total grain yield.

Keywords: Mixed cropping, irrigation, LER, yield performance, economic feasibility.

Introduction

Although food grain production has more than double since independence in 1971, food insecurity both in national and household level remains a matter of concern for the government (FAO, 2021). Half of the population can't reach the minimum dietary energy requirement (2122 kcal capita^{-1} day^{-1}) and one quarter of them subsist in extreme shortage of energy consuming less than 1800 kcal capita^{-1} day^{-1} (BBS, 2012). Apart from the prevailing deficit in total calorie intake, the normal diet of Bangladesh people is seriously imbalanced because of inadequate shares of fat, oil and protein (Unnayan Onneshan, 2013). This dietary imbalance reflects insufficient domestic production of non-cereal foods (pulses, oilseeds, fruits, meat, milk and eggs), low incomes, food preferences and lack of nutrition knowledge.

[1]University of Western Australia, 35, Stirling Highway, Crawley, WA 6009, Australia. [2]Krishi Gobeshona Foundation, BARC Complex, Farmgate, Dhaka 1215, Bangladesh. [3]Bangladesh Wheat and Maize Research Institute, Regional station, Gazipur 1701, Bangladesh. [4]RDRS Bangladesh, Jail Road, Rangpur, Bangladesh. *Corresponding author: mgneogi@gmail.com

The area under pulse crops has declined while the area under rice production has increased. About 75% of the total cropped area and over 80% of the total irrigated area is planted to rice (BRRI, 2021). As a result, very little land area has been left for the production of other essential commodities of life. Practically we have very little scope for increasing land area for non-rice crops, such as pulse, wheat, onion, garlic etc. Domestic pulse production satisfies less than half of the countries requirements. The rest some 0.75 million tons is imported at a cost of about US$ 32.2 million per annum (The Financial Express, 2021). Mixed or relay cropping is an important tool to meet diversified family need of various crops as well to increase production per unit land area. Such intervention can be adopted in Rabi season having favorable environment for growing non-rice field crops in Bangladesh.

Therefore, the priority of agriculture today has been shifted towards nutritional security of growing population (Das and Kabir, 2016). This nutritional security can be enhanced through the cultivation of pulses and oil seeds which are deficit in Bangladesh for many years. Pulses are considered as the protein of the poor as they have lesser access to animal proteins. Thus, the pulses are essential components of the daily diets of the people of Bangladesh. Annual demand of pulses in Bangladesh is about 2.5 million tons where only 0.89 million tons are produced in the country per year and thus 1.6 million tons are imported from other countries (AIS, 2016). Bangladeshis consume about 14.3 g of pulses per capita per day, which is far below the 50 g per day recommended by FAO/WHO (DDP, 2013).

Among the legume crops, lentil is the number one pulse in Bangladesh with respect to consumption. It is a rich source of dietary protein and micro-nutrients for majority of the people in the country and is eaten as soup called dal with rice (Sarker *et al*., 2004). The total cultivated area of lentil in Bangladesh is around 154,000 hectare while production of lentil is around 116,000 tons (BBS, 2020). However, per unit yield is lower compared to many other countries of the world. Besides, pulses need to compete with other crops for its space indicating that mixed cropping with wheat or other minor cereals can play an important role for nutrient security.

Mixed cropping is the practice of growing two or more crops on a single piece of land whose sowing time is same and harvesting time is also approximately similar. Mixed cropping of lentil with wheat helps farmers to avoid the risk of total crop failure and to increase total productivity per unit area. Lentil is grown mainly as a mono-crop in Bangladesh, but mixed cropping and inter-cropping with wheat, mustard, etc. is practiced in some areas (Nargis *et al.*, 2004). Traditionally, it is used by subsistence farmers primarily to increase the diversity of their products and to stabilize of their annual one output. But the traditional procedures for the generation and dissemination of technology on many crops are not adequate. For the generation of mixed cropping technology, a procedure is needed to measure the interaction among the crops grown on the same piece of land.

In our country, particularly in the winter, practice of mixed cropping might be more helpful than that in other seasons. A proper association of a pulse and a cereal crop might be a balanced diet for the subsistence farmers. In this country, many of us do not have balanced diet, remain undernourished and become easily susceptible to diseases. For some socioeconomic constraints general people of this country cannot intake animal protein and as such they have to depend on vegetables protein, bulk of which comes from pulses. Lentil is an important pulse crop containing about 23.7% protein as against 7.5% and 11.9% protein of rice and wheat, respectively (Bhatty, 1988). Wheat, a tall erect plant, does not drastically cut off solar radiation under certain population densities and thus can support associative growth of lentil. However, moisture stress can limit growth of winter crops. Mixed cropping of lentil with wheat helps farmers avoid the risk of total crop failure.

Rabi crops in Bangladesh suffer from moisture stress at the reproductive stage, especially if no rain occurs during March-April. Our experiences have shown that application of one or two irrigations can increase yield of Rabi crops substantially. The present study was, therefore, undertaken to find out a suitable mixing rate of wheat with usual seed rate of lentil without substantial reduction in lentil yield but to improve total land productivity. Another objective of the study was to measure the effects of different levels of irrigation on the performance of mixed culture.

Materials and Methods

The experiment was conducted in an experimental field of RDRS campus at Rangpur during Rabi season. The soil texture of the experimental plot was sandy loam with pH value of 5.6 and organic matter content of the soil was 1.6%, which may be considered low. The treatments imposed were a) three irrigation levels (no irrigation, 1 and 2 irrigation) and b) wheat and lentil mixing rates as follows-

Treatment code	% of wheat seed rate	% of lentil seed rate
T_1	0	100
T_2	10	100
T_3	15	100
T_4	20	100
T_5	25	100
T_6	30	100
T_7	35	100
T_8	40	100
T_9	45	100
T_{10}	50	100
T_{11}	100	0

The treatments were assigned in a split-plot design with three replications. Irrigation management was imposed in the main plots and wheat-lentil seeds were sown in the sub-plots randomly. Unit plot size was 3 m x 3 m. The experimental plot was first ploughed by a power tiller. Then ploughed and cross ploughed by country plough and were leveled by laddering. Cow dung was applied at the rate of 4.6 t ha^{-1} before final land preparation.

Seed rate used for wheat and lentil were 120 and 40 kg ha^{-1}, respectively. Urea, triple super phosphate (TSP) and muriate of potash (MoP) were applied at 30, 50 and 20 kg ha^{-1}, respectively during final preparation. The lentil and wheat cultivars selected for the experiment were BARI Mosur-5 and Kanchan, respectively. Both varieties were developed by Bangladesh Agricultural Research Institute (BARI) as high yielding varieties. Average germination percentage of lentil and wheat were 87% and 82%, respectively. Wheat and lentil seeds were sown on 13 November 2016. First irrigation was applied on 3 December and second irrigation was applied on 23 December 2016. Plots were properly weeded at the early stage of crops. No infestation of pest and diseases were noticed.

After maturity wheat was harvested on 21 March 2017 and lentil was harvested on 8 April 2017. The crops were dried, threshed, cleaned and again dried. Crop yields from individual plot were weighed and yield was expressed as kg ha^{-1}. Total protein content was computed from the wheat and lentil yield by multiplying with 0.125 and 0.235, respectively (Lina *et al.*, 2013). Land equivalent ratio (LER) was estimated in accordance with the following formula (Shaner *et al.*, 1982).

$$\text{LER} = \frac{\text{Yield of mixed crop (lentil)}}{\text{Yield of sole crop (lentil)}} \times \frac{\text{Yield of mixed crop (wheat)}}{\text{Yield of sole crop (wheat)}}$$

The LER index essentially compares productivity in intercropping with that in the monocrop, with high value of LER indicating the advantage of intercropping. The values exceeding 1.0, indicates that in spite of the competition for space, intercropping is always more productive than mono cropping.

Grain yield, total protein yield and LER were analyzed statistically according to split design. The relationship between different proportion (%) of wheat and LER were studied by using regression models. All these data were statistically analyzed according to split plot design with irrigation levels as the main plot and mixing rates in the sub plots.

Statistical analysis

Statistical analyses were performed with SAS package, version 9.1 (SAS, 2003). A two-way ANOVA was carried out to compare the treatment means. The DMRT was performed for mean comparison.

Results and Discussion

Lentil grain yield

Statistically significant yield differences of lentil were observed at varied levels of irrigation and with different proportions of mixing treatments. Lentil yields with no, 1 and 2 irrigations were 396.8, 471.2 and 499.8 kg ha^{-1}, respectively indicating that lentil yields were increased by 18-26% because of 1 and 2 irrigations. However, farmers generally grow lentil under residual soil moisture. Irrespective of irrigation, mean lentil yields as mixed crop with wheat are shown in Table 1. Lentil as a sole crop and with 10% of wheat seed rate gave significantly higher yield than other treatment combinations. Akhter *et al.* (2004) also reported almost similar findings. There was gradual decline in lentil yield with increasing proportions of wheat seed rate.

Lentil yield showed a decreasing tendency with higher rates of mixing wheat. But the decrease in lentil yield was not always

Table 1. Mean yield of lentil at different mixing rates of wheat over three levels of irrigation

Treatment code	Mixing rates (%)		Yield (kg ha^{-1})
	Wheat	Lentil	
T_1	0	100	625.3a
T_2	10	100	593.8a
T_3	15	100	519.8b
T_4	20	100	492.0bc
T_5	25	100	466.7bc
T_6	30	100	517.3b
T_7	35	100	471.4bc
T_8	40	100	444.5c
T_9	45	100	443.8c
T_{10}	50	100	440.8c
T_{11}	100	0	00.0d

Means followed by same letters are not significantly different at 5% level of DMRT

consistent with high rates of wheat mixing. Wheat mixing rates of 15% and 30% produced relatively higher yield of lentil and were statistically identical. Lentil yield obtained from 15 to 35% mixing rates of wheat did not show much yield differences, but at 40% and above mixing rates of wheat, lentil yield decreased significantly. This may be due to shading effect of wheat on lentil and high inter plant completion for nutrients and moisture. Wheat plants were comparatively taller than lentil plants; therefore, at high proportions of mixing wheat with lentil cause shading to the dwarf (lentil) crop and consequently, yield of lentil was affected.

Wheat grain yield

Wheat grain yield differed significantly because of irrigation regimes and its mixing proportion with lentil (Table 2). In general, grain yield of wheat increased progressively with its higher mixing rates. The highest grain yield of wheat was 1817 kg ha^{-1} as sole crop. Similar result was reported by Çiftçi and Ülker, (2005) and Wang *et al.* (2013) with barley. On average over irrigation, the lowest wheat grain yield of 627.8 kg ha^{-1} was recorded when 10% of wheat seed rate was used. But when 20% wheat seed rate was used in the mixture, wheat yield was not doubled as that obtained with 10% wheat seed in mixture. In the same way with each successive high rate of wheat seed in the mixture resulted in additional yield which were not proportional if compared with the yield of wheat obtained from mixing of 10% wheat seed. But wheat yield did not increase proportionately with high proportion of mixing wheat with lentil. This disproportional increase in wheat yield with higher rates of mixing wheat with lentil might be due to competition of space, moisture and nutrients. However, our objectives of mixing different proportions of wheat with full seed rate of lentil was to find out a suitable mixing

Table 2. Effect of interaction of seed mixing rates and irrigation levels on yield of wheat

Wheat-lentil mixing rate (%)		Irrigation levels			Mean yield (kg ha^{-1})
Wheat	Lentil	0	1	2	
0	100	0.0d	0.0f	0.0g	0.0h
10	100	470.4a	692.6le	720.4f	627.8g
15	100	525.5a	814.9d	879.7f	740.0g
20	100	920.4b	956.0d	1149.4e	1008.6f
25	100	826.0c	1220.0b	1540.4d	1195.5cd
30	100	887.0c	1067.0bc	1525.7d	1159.9d
35	100	874.0c	1131.0b	1705.0c	1236.7bcd
40	100	967.4b	1031.1bc	1882.7b	1293.7c
45	100	914.8bc	1125.4b	1827.4bc	1289.2b
50	100	887.0c	1192.0b	1842.4bc	1307.1b
100	0	1329.0b	1751.4a	2371.4a	1817.3a
Mean yield (kg ha^{-1})		8601.5C	10981.4B	15444.5A	

Similar small letters in column and capital letters in row compare means at 5% level of DMRT

rate of wheat, so that some additional yield of wheat could be received without significant decrease in lentil yield. In general, irrigation acted synergistically for improvement of wheat grain yield irrespective of wheat seed rate mixed with lentil.

Combined grain yields

The highest mean combined grain yield was 1904.5 kg ha^{-1} with two irrigations followed by 1469.7 kg ha^{-1} with single irrigation and the least with no irrigation (1173.3 kg ha^{-1}) indicating that total grain yields increased by 23-62% depending on irrigation regimes. Grain yields of sole lentil and wheat were 625.3 and 1817.3 kg ha^{-1}, respectively (Table 3). Mixing of wheat seed at variable rates with lentil increased total production of these two crops as compared to sole crop culture. Although sole wheat gave the highest grain yield (1817.3 kg ha^{-1}), use of full lentil rate and 25-50% of wheat seed rate can be grown for improving total land productivity than their sole culture. Moreover, there are additional benefit of capturing atmospheric nitrogen (N) by legumes and its transfer to associated crops (Fujita *et al*., 1992) and thus helps in reducing reactive N species in the environment related to synthetic N fertilizer applications

Percentage of total grain yields ranges from about 95% to 172% depending on wheat-lentil mixing proportions (Table 4). The study suggested that wheat could be mixed up to 35% with lentil without much reduction in lentil yield. Mixing of 35% seed rate of wheat with lentil could produce approximately 65% additional yield over sole lentil culture. Singh *et al*. (1996) reported that the combined yield of wheat and lentil under wheat + lentil intercropping system was significantly higher than that of the sole crop.

Table 3. Mean combined yield of lentil and wheat at different mixing rates of wheat over three levels of irrigation

Treatment code	Mixing rates (%)		Yield (kg ha^{-1})	% increase over sole lentil
	Wheat	Lentil		
T_1	0	100	625.3e	-
T_2	10	100	1221.6d	95.4
T_3	15	100	1259.7d	95.5
T_4	20	100	1500.7c	132.9
T_5	25	100	1662.3b	158.0
T_6	30	100	1677.4b	160.3
T_7	35	100	1708.3ab	165.1
T_8	40	100	1718.5ab	166.7
T_9	45	100	1733.3ab	169.0
T_{10}	50	100	1749.4a	171.6
T_{11}	100	0	1817.3a	-

Small letter in column compare means at 5% level of probability by DMRT

Table 4. Protein yield as influenced by irrigation levels and mixing rates of wheat

Wheat-lentil mixing rate (%)		Irrigation levels			Total (kg ha^{-1})	Mean (kg ha^{-1})
Wheat	Lentil	0	1	2		
0	100	124.3f	156.3d	164.2g	444.8	148.3e
10	100	183.0c	235.4b	206.03efg	624.4	208.1d
15	100	175.0d	227.4bc	244.7def	647.1	215.7d
20	100	217.8a	237.2b	273.2def	728.2	242.7bc
25	100	201.1b	269.8a	309.4bcd	780.3	260.1ab
30	100	211.9a	262.9a	328.1abc	802.9	267.6a
35	100	212.4a	249.4b	337.3ab	799.1	266.4ab
40	100	209.1ab	229.5bc	355.3a	793.9	264.6ab
45	100	209.1ab	254.4a	338.7ab	802.2	267.4ab
50	100	195.6c	260.6a	348.2ab	804.4	268.1a
100	0	166.2e	219.0bc	296.5cde	681.7	227.2cd
Mean (kg ha^{-1})		2105.5C	2601.9B	3201.6A		

Means in a column and row followed by same letters are not significantly different at 5% level of DMRT

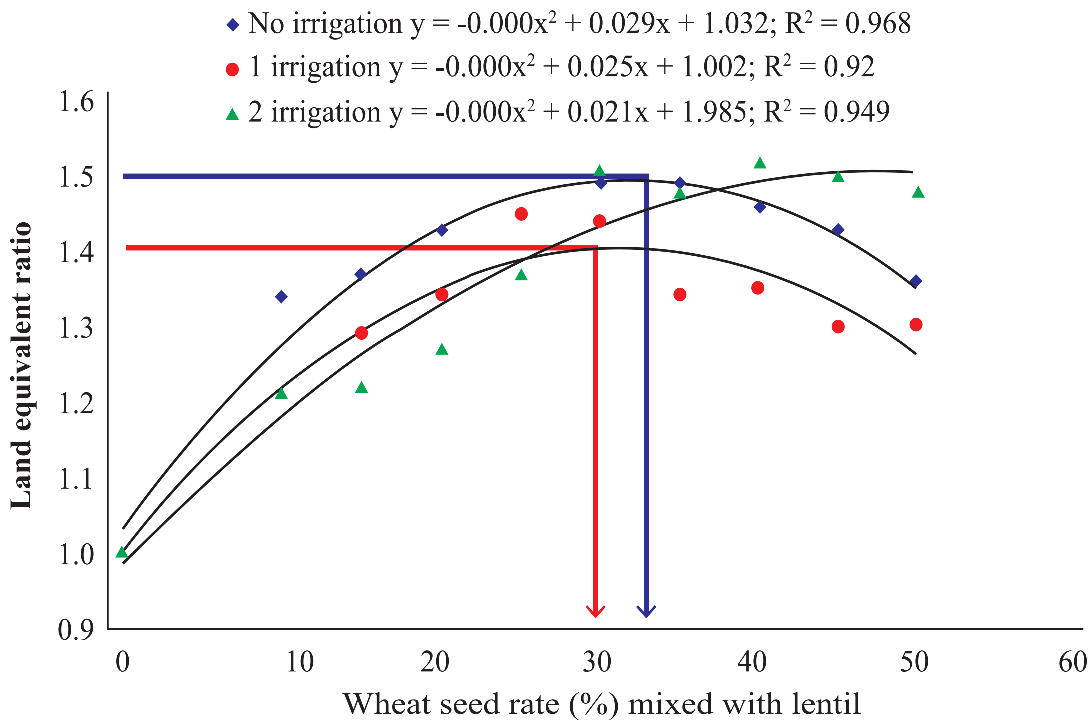

Fig. 1. Land equivalent ratios as influenced by mixing rates of wheat with lentil at three levels of irrigations.

Total protein yield

Mean yield of protein was highest (3201.6 kg ha^{-1}) with application of two irrigations irrespective of wheat-lentil mixing proportions, followed by single irrigation and the least with no irrigation (Table 4). If 25-50% of wheat seed rate is considered irrespective of irrigation regimes, the mean protein yield was 260-168 kg ha^{-1}. This clearly indicates that total protein yields could be increased based on wheat-lentil mixed culture than their sole cropping. Similar results were reported by Wang *et al.* (2013) where they found increased protein yields in wheat and barley grain depending on their growing ratios with lentil.

Land equivalent ratio

Levels of irrigation had no significant effect on LER, but mixing rate of wheat influenced it and ranged from 1.21-1.52 (Fig. 1). The highest LER values were obtained with mixing about 30-35% of wheat seed rate. However, LER values obtained with mixing of 25-35% of wheat seed rates appeared to be more acceptable based on grain yield increase. The values of LER obtained with two irrigations were statistically identical with mixing of 30-50% wheat seed rate. However, no definite trend was observed in LER improvement, which is similar with the findings of Akhter *et al.* (2004). Regression models indicated that mixing of about 30-35% of wheat seed rate were beneficial for obtaining higher LER. The

LER was high at about 30% mixing rates of wheat with zero and that of 35% for single irrigation levels. With two irrigation regimes, it seems that about 45% wheat seed could be mixed with lentil for higher LER.

Conclusion

Irrigation had positive effects on the yields of lentil and wheat. Sole lentil crop gave high yield though mixing of 15-35% of wheat seed rates was satisfactory. At mixing rates of 40% and above lentil yield decreased significantly. The highest wheat and total grain yields were obtained with two irrigations than others. Total grain yield of lentil and wheat increased by 25 and 62% with single and two irrigation regimes, respectively. Moreover, wheat-lentil mixed cropped was beneficial in terms of total yields and protein yields than their sole cropping. The LER values were also higher with mixing of 30-35% of wheat seed rate. Since there is a land scarcity for growing pulses in Bangladesh, wheat can be grown successfully as a mixed crop with lentil, provided its seed rate is limited within 15-35% of normal rate. Such practice can alleviate nutrient security by providing additional grain yield and protein.

References

AIS (Agricultural Information System). 2016. Annual Report. Department of Agriculture, Ministry of Agriculture, Dhaka.

Akhter, N., M. A. Alim, M. M. Islam, J. Naher, M. Rahman and A. S. M. I. Hossain. 2004. Evaluation of mixed and inter-cropping of lentil and wheat. *J. Agron*. 3(1): 48-51.

BBS. 2012. Statistical Year Book of Bangladesh, Bangladesh Bureau of Statistics, Ministry of Planning, Government of People's Republic of Bangladesh, Dhaka.

BBS. 2020. Statistical Year Book of Bangladesh, Bangladesh Bureau of Statistics, Ministry of Planning, Government of People's Republic of Bangladesh, Dhaka.

Bhatty, R. 1988. Composition and quality of lentil (*Lens culinaris*). A review. *Canadian Inst. Food Sci. Technol. J.* 21(2): 144-160.

BRRI. 2021. Bangladesh Rice Knowledge Bank. Gazipur. http://www.knowledgebank-brri.org/riceinban.php.

Çiftçi, V. and M. Ülker. 2005. Effect of mixed cropping lentil with wheat and barley at different seed ratios. *Agron. J.* 4(1): 1-4.

Das, S. and W. Kabir. 2016. Pulses Production in Bangladesh: Status and Drivers for Enhancement. An international conference on Pulses for Sustainable Agriculture and Human Health organized by IFPRI, Delhi, Pusa.

DDP. 2013. Desirable diet for Bangladesh: A desirable dietary intake has been proposed after the evaluation of previous work and current consumption patterns of the population, DDP, 2013, BIRDEM with the support of National Food Policy Capacity Strengthening Programme (NFPCSP).

FAO. 2021. Report on the state of food security and nutrition in the world. Transforming Food Systems for Food Security, Improved Nutrition and Affordable Healthy Diets for all. Rome, Italy 236 P.

Fujita, K., K. G. Ofosu-Budu and S. Ogata. 1992. Biological nitrogen fixation in mixed legume-cereal cropping systems. *Plant Soil*. 141: 155-175.

Islam, Q. M. S. and M. O. Ali. 2002. Research Report on Pulses socio-economics. A report of PRC, BARI, Ishurdi, Pabna, Bangladesh. Pp. 1-15. ICARDA, Aleppo, Syria.

Miah, A. A. and M. M. Rahman. 1993. Agronomy of lentil in Bangladesh. Pp. 128-138. Erskine, W. and Saxena, M. C. (ed.) *In*: Proceedings of the Seminar on lentil in South-Asia, 11-15 March 1991. New Delhi, India.

Nargis, A., M. A. Alim, M. M. Islam, Z. Nahar, M. Rahman and A. S. M. Iqbal Hossain. 2004. Evaluation of Mixed and Intercropping of Lentil and Wheat. *J. Agron.* 3: 48-51.

Sarker, A., W. Erskine, M. A. Bakr, M. M. Rahman, M. A. Afzal and M. C. Saxena. 2004. Lentil improvement in Bangladesh. APAARI Publication: 2004.

SAS (Statistical Analysis System). 2003. SAS Institute, Cary, North Carolina, USA.

Singh, R. K., S. Ganga and G. Saran. 1996. Nutrient management in wheat-lentil inter-cropping system under dry land conditions. *Annals Agric. Res*. 17(3): 272-280.

The Financial Express. 2021. Pulses import rises amid static local output. Published on 16 September, 2021.

Unnayan Onneshan. 2013. Poverty, Hunger, Nutrition, and Food Production in Bangladesh. Unnayan Onneshan, Dhaka, Bangladesh. Retrieved on November 1, 2013.

Wang, L., S. Gruber and W. Claupein. 2013. Mixed cropping with lentils increases grain protein of wheat and barley. *J. Kulturpflanzen.* 65(11): 422-426.