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Review Paper

WHEAT-BASED INTERCROPPING: A REVIEW

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ABSTRACT

The world's population is increasing rapidly, and in order to feed it, one of the most attractive strategies is to increase productivity per unit area of available land or to increase the land area under production, which seems shrinking day by day. Therefore, to maximize land use and production, the ultimate goal of agriculture, namely yield, intercropping is an advanced agronomic technique that allows two or more crops to yield from the same area of land. Better utilization of resources and reduced weed competition minimize the risk of food shortages by enhancing yield stability. Several factors can affect intercropping: plant density, sowing time, the maturity of a crop, the selection of crop that is compatible with another as well as farmers' and the region's socioeconomic conditions. In intercropping, the land equivalent ratio (LER) is used to measure the productivity of land. Since wheat is the most important cereal around the world and is most suitable for intercropping, this review focuses on wheat-based intercropping.

Key words: intercropping, Wheat, land equivalent ratio, weeds, pests, resource utilization

Abbreviations: LER, land equivalent ratio; **LAI**, leaf area index

INTRODUCTION

Intercropping in the broader context of food security and good agronomic practice: Food shortage is prevalent in many parts of world, particularly in Asia and Africa, due to the rapid rise in population. One possible approach to resolve this problem would be to maximize the utilization of limited agriculture land through multiple cropping to increase productivity per unit area of available land (Seran *et al.,* 2010; Khan *et al.,* 2014), for which there are many examples, e.g. intercropping of legumes and barley (Alizadeh and Teixeira da Silva, 2013). Intercropping, which has long been a common practice in developing countries (Wahla *et al.,* 2009) (Table 1), is an important multiple cropping system (Zhang and Li, 2003). Intercropping offers potential benefits relative to monoculture by increasing yield through the effective use of resources, including water, nutrients, solar energy (Morris and Garrity, 1993; Nasri *et al*., 2014). Diversity in the farming system is also expanded, which in turn brings stability (Mousavi and Eskandari *et al.,* 2011), reduces the incidence of diseases (Eskandari, 2012), improves soil fertility (Lithourgidis *et al.,* 2011; Swer and Dkhar, 2014), sustains productivity (Ünlü *et al.,* 2010; Gao *et al*., 2014) and enhances weed and insect control (Saudy and El-Metwally, 2009; Mitku *et al*., 2014; Uddin and Adewale, 2014). Most importantly, food security can be achieved (Ouma and Jeruto, 2010), which is essential since wheat is the bread-basket of much of the Asian subcontinent (Hossain and Teixeira da Silva, 2013). In developing countries, intercropping is superior to monocropping in terms of farm income, which is key motivation for farmers who reaped a double crop and a double income when wheat (*Triticum aestivum* L.; cv. 'Inqalab91') was intercropped with chickpea (*Cicer arietinum* L) (Akhtar *et al.* 2010).

Intercropping: Intercropping is a system of management of crop which involves growing of two or more dissimilar crop species or varieties simultaneously in distinct row combination on the same piece of land (Katyayan 2005).

Efficiency of resource utilization can be increased with intercropping (Tilman *et al.* 2002; Gao *et al*., 2014; Nasri *et al*., 2014). According to Sullivan (2003) intercrops staggered the maturity dates or development periods and take advantage of variations in peak resource demands for nutrients, water, and sunlight.

In comparison with corresponding sole crop, higher agricultural resource utilization of intercropping was observed in most studies. Tsubo *et al*. (2001) carried out a study to compare the production efficiency in intercropping (maize/been) with sole cropping (maize and been) in terms of radiation use efficiency (RUE). The authors concluded that the intercrop fraction of intercepted radiation and RUE was higher compared to sole cropping. Similar results were also observed by Awal *et al*. (2006) who reported greater RUE in intercropping of maize/peanut in comparison with sole cropping of maize and peanut.

Table 1. Intercropping systems in different countries

Country	Intercropping system / Component crops		References
Malawi	Maize	Gliricidia	Akinnifesi *et al.(2006)*
Uganda	Coffee	Banana	Asten *et al*. (2011)
Ethiopia	Tef	Sunflower	Bayu *et al*. (2007)
South Africa	Sugarbean, Peanut	Sugarcane	Berry *et al.* (2009)
Bangladesh	Wheat	Chickpea, Lentil	Das *et al., (2011)*
Iran	Barley	Annual Medic	Esmaeili *et al.* (2011)
Iran	Canola	Faba Bean	Gharineh and Moosavi (2010)
India	Soybean	Pigeon Pea	Ghosh *et al*, (2006)
Mali	Sorghum	Cowpea	Gilber *et al.*, (2003)
Pakistan	Rice	Sesbania, Cowpea, Pigeon pea, Mung bean, Rice bean	Jabbar *et al*. (2010)
Pakistan	Maize	Mash	Ehsanullah *et al*. (2011)
Pakistan	Wheat	Lentil	Khaliq *et al.(2001)*
Pakistan	Maize	Mung	Khan *et al*., (2012)
Kenya	Maize	Sorghum	Khan *et al.* (2007)
Sudan	Sorghum	Cowpea	Mohammed *et al.* (2008)
Nepal	Maize	Soybean	Prasad and Brook (2005)
Srilanka	Brinjal	Groundnut	Prashaanth *et al*. (2010)
Pakistan	Wheat	Fenugreek	Wasaya *et al.* (2013)
China	Wheat	Maize	Gao *et al.* (2014)
Pakistan	Wheat	Brassica	Khan *et al.*, (2014)

According to Li *et al*. (2009) intercropping upland rice/mung bean improved the formation of arbuscular mycorrhizas, in the upland rice roots. The authors reported an improved formation of mycorrhizas by the intercropping increased total P uptake by 57% in rice, total P and N acquisition by 65% and 64% respectively in mung bean, and nodulation by 54% in mung bean. Intercropping of wheat/maize and wheat/soyabean showed a clear advantage over sole cropping in terms of biomass and nutrient accumulation (Li *et al*. 2001).

A study of agro forestry, *G. sepium* hedgerows reduced crop yield, and nitrogen use efficiency (crop N uptake during the first season) was less in the *G. sepium* intercropping system than in monoculture (Rowe *et al*., 2005), water use efficiency (Morris and Garrity, 1993), and Agegnehu (2008) intercropped wheat with faba bean (*Vicia faba* L.) to compare with sole culture of each species during 2002 and 2003, in the central highlands of Ethiopia and reported that mixed intercropping increased the land equivalent ratio by +3% to +22% over sole cropping. Similar observations have been reported by other researcher in terms higher land use efficiency of intercropping over sole cropping (Zhang *et al*. 2007; Banik *et al*. 2009). Other potential benefits of intercropping include high productivity and profitability (Yildirim and Guvence, 2005), increase in soil fertility through nitrogen fixation by addition of leguminous crop in intercropping system (Hauggaard-Nielsen *et al*., 2001), reducing damage caused by pests, weeds and diseases (Sekamatte *et al*., 2003, Banik et al. 2006), improvement of quality of forage (Agegnehu *et al*. 2006; Barillot *et al.*, 2014) and use of environmental resources efficiently (Knudsen *et al.*, 2004, Eskandari and Ghanbari, 2010).

Wide spread acceptance of intercropping systems have not occurred because agriculture technology, modern crop varieties, government farm policies and research efforts are concentrated on production of monocultures not poly cultures (Vandermeer, 1989; Kirschenmann, 2007). Due to significant drawbacks in modern agriculture system, interest in intercropping system developed for the production of food and fiber (Kirschenmann, 2007). Roberts *et al.* (1989) stated that wheat is the most suitable cereal for intercropping. There is immense need to identify the component crop with high yield advantage and good competitive ability to maximize production.

ASPECTS TO BE CONSIDERED

For successful intercropping, there is need to have several consideration before and during cultivation.

Maturity of Crop: There will be biggest yield advantage, when main crop and intercrop have different growing period in order to make their major demand of resources at different times. Singh and Gupta (1994) stated that competition between principal and subsidiary crop depend upon maturity period, canopy spread and rooting habit of component crops. Li *et al.* (2011) studied intercropping system of wheat/ maize, wheat/ feba bean and maize / feba bean and observed that by using species having different maturity dates can be more effective in decreasing soil mineral nitrogen accumulation and increasing crop nitrogen use efficiency.

Plant density: Low plant population resulted into low yield (Jeyakumaran and Seran, 2007). Ghanbari-Bonjar and Lee (2003) demonstrated that while comparing intercrop to sole crop, success of intercrop can be determined by lot of agronomic practices including; relative density of component crops, the intimacy with which crops are intercropped and supplies of limited resources. Seran and Brintha (2010) reported that adjustment is made in seedling rate of component crops in mixture to optimize the planting density. Reasonable Leaf Area Index (LAI) is critical to maintain high photosynthetic rate and yield (Xiaolei and Zhifeng 2002). Liebman and dyck (1993) concluded that land equivalency ratio resulted into an increase when intercrops are seeded at higher densities. Raouf *et al.* (2003) carried out field experiment on intercropping of two wheat cultivars; one was tall (110 cm.) and other was dwarf (65 cm.). Both cultivars were grown with six sowing ratios and 3 seeding densities. They observed 9.13% higher yield in sowing ratio of 40:60 grown at seeding density higher than optimum. This yield was greater than maximum yield which was obtained in monoculture of one of tall cultivar.

Compatible crops: Many studies have been shown that intercropping can be more productive compared to monoculture but intercropping can result into competition for resources (Humphries *et al.,* 2004; Harris *et al.,* 2008). Among different resources of competition, light is one of them (Egan and Ransom, 1996). Soil moisture is another potential source of competition (Humphries *et al.,* 2004). Among other sources; there is competition for nutrients between plants that could reduce the yield of mono crop. Crop competition can be reduced by spatial arrangement. Mixing species in cropping system lead to lot of benefits. These are expressed on various space and time scales, from increase in crop yield and quality on short term basis and ecosystem sustainability on long term basis (Malezieux *et al.,* 2009). Proper combination of crop is very important in intercropping. Advantages in terms of yield occur when component crop of intercropping system compete only partly for the same plant growth resources and inter-specific competition is less than intra-specific competition (Vandermeer, 1989). There is need to screen out the crop for compatibility (Baidoo *et al.,* 2012) with an objective to utilize maximum resources per unit area with maximum yield benefits and least competition between component crops. Khan *et al.* (1999) revealed that intercropping of wheat and gram grown in ratio of 3:1 and 1:1 resulted into maximum seed yield and monitory returns as compared to sole crops. Gill *et al.* (2009) reported that chick pea and wheat is intercropped in several countries but mutual affects of both crops on root proliferation is hardly reported. Zhang and Li (2003) observed that in case of wheat/ maize and wheat/ soybean intercropping system, there was significant increase in yield up to 74% and 53% in intercropped wheat with maize and soybean respectively compared to sole crop. It is likely the result of inter-specific competition for nutrients as wheat has higher competitive ability than that of maize or soybean. Gooding *et al.* (2007) carried out field experiments on intercropping of wheat and faba bean and observed a clear reduction of wheat yield up to 25 -30% compared to sole wheat crop. Subedi (1997) stated that intercropping of Brassica (*Brassica campestris* var. *toria*) could not perform well as compared to pea (*Pisum sativum* L.) (Table 2).

Table 2. Changes in component crop and overall yield in case of different intercrops with wheat

Study	Main crop	Intercrop	Country	Outcomes
Bhim *et al.* (2005)	Wheat	Pea	Bhutan	Overall yield increased
Gooding *et al. (*2007)	Wheat	Faba Bean	UK	Overall yield decreased
Khan *et al.* (2005)	Wheat	Chickpea	Pakistan	Main crop yield increased
Magid *et al.* (2008)	Wheat	Alfalfa	Saudi Arabia	Intercrop yield increased
Nazir *et al.* (2002)	Wheat	Sugarcane	Pakistan	Intercrop yield decreased
Qayyum *et al.* (2011)	Wheat	Onion	Pakistan	Overall yield increased
Woldeamlak *et al.* (2009)	Wheat	Barley	Eritrea	Overall yield increased
Yang *et al.(* 2010)	Wheat	Maize	China	Overall yield increased
Zhang and Li (2003)	Wheat	Maize and Soybean	China	Overall yield increased
Wasaya *et al*. (2013)	Wheat	Fenugreek	Pakistan	Overall yield increased
Gao *et al.* (2014)	Wheat	Maize	china	Overall yield increased
Khan *et al.* (2014)	Wheat	Brassica	Pakistan	Overall yield increased

Wheat- legume intercropping: Adesogan *et al*. (2002) described that for development of sustainable food production system, intercropping of cereal and legume is very important particularly where there are limited external inputs. Intercropping of cereal and grain legume is neglected in agriculture science and practice in organic as well as conventional farming system (Dahlmann and Fragstein, 2006). According to Sherma *et al.* (1993) mixture of legume and cereal result in higher yield than their respective sole crop. Previous work showed that intercropping of alfalfa in wheat increased yield as well as protein content of wheat (Magid *et al.*, 2008).

Mandal *et al.* (1991) concluded that wheat and chickpea intercropping gave higher yield of wheat as well as water use efficiency than wheat and rapeseed intercropping. In various wheat-mustard intercropping treatments, the lowest wheat yield was achieved at highest mustard population and vice versa (Srivastava and Bohra, 2006). Ghaley *et al.* (2005) carried out field experiment to study the sole and intercropping of field pea and spring wheat on crop yield and fertilizer and soil nitrogen use. Three levels of urea fertilizer were used i.e. 0, 4 and 8 g nitrogen m^{-2}. It was revealed that intercropping of pea and wheat resulted into maximum productivity without addition of nitrogen fertilizer. Li *et al.* (2001) observed that in wheat/Soybean intercropping, there was recovery of growth of soybean after harvesting wheat. Significant effect due to the association of chick pea, lentil and rapeseed on different yield and yield components of wheat has been shown in previous study. Khan *et al.* (2005) carried out field experiments to study effect of rapeseed, lentil and chickpea in different proportion on yield and yield components of wheat. They concluded that plant height, spike length, number of grains per spike and grain yield of wheat was higher when intercropped with chickpea with proportion of 1:1.

Wheat-non legume intercropping: Woldeamlak *et al.* (2009) observed increased yield up to 122% compared to sole crop for different combination of different varieties in barley-wheat intercropping and concluded that barley-wheat intercropping system is more efficient due to maximum utilization of resources. Yang *et al.* (2010) observed the effect of strip intercropping of wheat and maize with width of 80cm each. They also observed more root development at most of soil depth and yield advantages in intercropping system compared to sole crop. Nazir *et al.* (2002) conducted experiments on wheat-sugarcane intercropping with 90 cm spaced double rows and reported reduction in cane yield up to 18% but net income was enhanced due to additional harvest of wheat than sole crop. Hiroyuki *et al.* (2001) carried out field experiments to check the effect of intercropping method on growth and yield of watermelon as well as drainage of soil. Wheat was grown as cover crop between ridges. It was concluded that due to intercropping, soil between ridges dried which resulted into enhancement in drainage. Li *et al.* (2001) observed recovery of maize growth after harvesting wheat, in wheat/maize intercropping. Rate of dry matter accumulation in maize was lower initially but increased after wheat harvest..

Wheat- vegetable intercropping: Wang *et al.* (2009) carried out experiment with wheat, soybean and oat as intercrop in cucumber and observed that cucumber intercropping wheat showed best results and promoted cucumber growth and yield. Singh *et al.* (2000) observed mean reduction in wheat grain yield upto 44.89 % in case of intercropping with potato after earthing up. Subedi (1997) concluded that intercropping of wheat and pea was profitable in terms of economic return as overall grain yield was maximized and recommended that sowing pea at rate of 30-45 kg ha^{-1} and wheat at rate of 120 kg ha^{-1} was more profitable. Qayyum *et al.* (2011) reported reduction in weed density in case of intercropping of wheat, onion and garlic in 4:2 rows strips. Maximum grain yield (5.17 t ha^{-1}) was obtained in sole wheat crop and minimum (2.23 t ha^{-1}) from intercropping of wheat and garlic in 3:2 row strips but total biomass yield in intercropping system was fairly high enough to compensate losses.

Time of Planting: In intercropping, component crop may not be sown or harvested at exactly the same time but they are simultaneous for significant part of their production cycle or growing period (Srivastava *et al.*, 2008). Machado (2009) reported four subcategories of intercropping i.e. mixed, relay, row and strip intercropping. Akter *et al.* (2004) evaluated the performance of mixed and intercropping of wheat and lentil and concluded that line sowing performed better than sole broadcast sowing. They also observed that lentil, wheat mixed seed rate decreased lentil yield over sole lentil crop sown through broadcast method. Gill *et al.* (2009) carried out pot experiment to explore the effect of mixed intercropping of wheat and chickpea and concluded that wheat has inhibitory effect on total biomass, root proliferation and grain yield of chickpea. Kaut *et al.* (2008) reported that mixture of wheat and oat at a seeding ratio 25:75 showed increased yield potential than sole crop. Woldeamlak *et al.* (2008) studied whether mixed cropping was more stable than sole cropping in case of wheat and barley and concluded that yield stability was more in case of mix cropping of wheat and barley. Wallace *et al.* (1992) reported that due to inter-seeding or relay cropping soybean in standing wheat, there was no difference in yield of inter-seeded and monocrop soybean planted on same day. Dua *et al.* (2007) evaluated wheat-potato relay intercropping system and concluded that yield of potato was not influenced by relay intercropping but highest grain yield was obtained in sole wheat crop (Table 3).

Table 3. Effect of stand geometry on wheat based intercropping system.

Intercropping System	Row ratio	Seed yield (t ha^{-1})			References , country
		Base crop	intercrop	Respective sole crops	
Wheat + Faba bean	1:1	1.01	4.23	4.85 +2.33	Eskandari and Ghanbari (2010), UK
Wheat + Potato	1:1	1.21	28.82 (tuber yield)	2.17 + 30.06 (tuber yield)	Dua *et al.* (2007), India
Wheat + Lentil	1:1	1.38	0.69	1.27 + 2.70	Akter *et al.* (2004), Bangladesh
Wheat +Lentil	1:2	0.94	0.89	1.27 + 2.70	Akter *et al.* (2004), Bangladesh
Wheat +Lentil	1:3	0.96	0.73	1.27 + 2.70	Akter *et al.* (2004), Bangladesh
Wheat +Gram	10:10	3.47	2.63	4.23+1.19	Munir *et al*. (2004), Pakistan
Wheat+Methra	4:4	3.12	0.74	4.18+1.24	Nazir *et al.* (2000), Pakistan
Wheat+Gram	1:1	1.66	0.81	1.76+1.39	Khan *et al. (*1999), Pakistan
Wheat+Gram	3:1	1.52	0.78	1.76+1.39	Khan *et al. (*1999), Pakistan
Wheat+Maize	6:2	3.47	7.42	5.54+10.34	Yang *et al.* (2010), China

BENEFITS OF INTERCROPPING

Resource utilization: Yield advantage in intercropping are mainly due to efficient utilization of resources such as light, water and nutrients than respective sole crop (Liu *et al.* 2006). Gao et al. (2014) carried out study on wheat-maize intercropping system and revealed that Nitrogen use efficiency was significantly higher in intercropping compared to sole cropping. Zhang and Li (2003) conducted field experiments on wheat- maize and wheat-soybean intercropping and observed that there was increase in uptake of nitrogen up to 50 and 59%, respectively in case of wheat-maize intercropping, respectively and 23 and 19% in case of wheat-soybean intercropping respectively. Barillot *et al*. (2014) found significantly higher radiation use efficiency in wheat-pea intercropping than that of sole crop. It was attributed to above ground and below ground interaction. Ali (1993) conducted field trails on wheat/chickpea intercropping and observed that 2:2 row resulted in more light interception and transmission to lower canopy which resulted in more land equivalent ratio and yield. Eskandari (2011) conducted intercropping affect of wheat and faba bean and described that intercropping system had a marked effect on environmental resource utilization in terms of more light interception, water and nutrient uptake compared to sole crop. Li *et al.* (2001) stated that intercropping is advantageous in terms of yield and nutrient acquisition. They observed that it was advantageous up to 40-70% in case of wheat intercropped with maize and 28 -30% in case of wheat intercropped with soybean.

Weed Control: Intercropping resulted in lower weed infestation level (Liebman and Dyck 1993; Midmore 1993). Szumalgaski (2005) described most important cause of weed suppression in intercropping system and stated that as intercrop capture more light than sole crop due to its different height and growing habit. Banik *et al.* (2006) carried out field experiments on wheat – chickpea intercropping and monocropping. Row to row spacing was maintained 20 and 30cm. They observed the fact that intercropping resulted in increase in total productivity per unit area, improvement in land use efficiency and weed suppression. Carr *et al.* (1995) reported that intercropping wheat with lentil resulted in reduction in weed biomass up to 96% in one year and 68% in another year than sole cropped lentil. Bulson *et al.* (1997) conducted field trails to clarify the effect of plant density on intercropped wheat and field bean and observed that weed biomass in intercrop was significantly reduced when seeding density of wheat and field bean was increased. Eskandari and Ghanbari (2010) studied the impact of intercropping of wheat and bean on grain yield, dry matter production and weed biomass and concluded that weed biomass was reduced in intercropping system as compared to wheat and bean sole crop. Eskandari (2011) conducted field experiments on intercropping of wheat and faba bean and reported that intercrop was more effective in weed suppression than wheat sole crop and he attributed this to less availability of environmental resources to weeds in intercropping system. Szumigalski and Van Acker (2005) observed greater weed suppression in case of intercrop as compared to their sole crop when wheat-canola and wheat- conola- Pea were intercropped. This indicated some sort of synergism among crops with in intercrops regarding weed suppression.

Pest and diseases: Trenbath (1993) described that in intercropping system components are often less damaged by pest and diseases than sole crops. Ra¨mert *et al.* (2002) concluded that among different methods of intercropping, strip cropping has potential to increase crop yield by suppressing pest outbreak. Ma *et al.* (2007) studied strip cropping of wheat and Alfalfa to improve the biological control of wheat aphid (*Macrosiphum avenae*) by the mite (*Allothrombium ovatum*) and concluded that mean number of mites per parasitized aphid was significantly more in strip cropping than in wheat monoculture. Bulson *et al.* (1997) described that level of disease on wheat was low in wheat and field bean intercropping when bean density was increased. Wang *et al.* (2008) studied the effect of intercropping of oil seed rape and garlic in winter wheat. They concluded that population density of *Sitobion avenae* was significantly decreased in intercropping system than in sole crop. Elevated level of aphid parasitoids was observed in case of wheat-oilseed rape intercropping field. Lennartsson (1988) observed that wheat and *Madicago lupulina* grown in mixture reduced the incidence of take all disease (*Gaeumannomyces graminis*) of wheat due to soil born pathogen. Vilich-Meller (1992) described that there was reduction in incidence of leaf fungal diseases in case of mixture of winter rye with winter wheat.

Erosion Control: Davidson (1994) described that well managed strip intercropping system could result into greater soil and water conservation potential than most of the monocropping systems. Chen *et al.* (2010) observed that intercropping of wheat and potato grown in strips up to 5m can reduce wind erosion, soil desertification and degradation effectively. Chen *et al.* (2010) concluded that wheat-potato intercropping resulted into reduction in wind erosion. They also stated that effective width of strip for control of wind erosion should be greater than or equal to 5.5 meters.

Yield advantages: Yield of intercropping system is often higher than in sole cropping system (Lithourgidis *et al.*, 2007; Dahmardeh *et al.*, 2009). The competitive relationship between the component crops, efficient utilization of land and overall productivity of intercropping system can be accurately assessed with the help of Land Equivalent Ratio (LER) (Rashid *et al.*, 2002). In order to measure the land productivity, land equivalent ratio is common index which is used in intercropping (Seran and Brintha, 2009). LER greater than one is indicator of more efficient utilization of land in intercropping system. It is due to more efficient utilization of resources in intercropping (Willey and Osiru, 1972) or by increased plant density (Fisher, 1977). LER showed benefits of cereal –legume intercropping (Mandal *et al.*, 1990). Wheat-maize intercropping showed significant advantage over sole cropping with respect to resource utilization (Gao *et al*., 2014). Ali *et al.* (2000) revealed that cost benefit ratio, land equivalent ratio and net income were higher ie. 2.46, Rs. 22486.98 and 1.17 respectively in 2:1 row canola wheat intercropping system. Raouf *et al.* (2003) observed that intercropping of different tall and dwarf wheat cultivars grown at seeding ratio of 40:60 resulted into 9.13 % higher yield than maximum which was obtained in monoculture of one of tall cultivar. Highest LER (1.12) was observed with same seeding ratio. Khatun *et al.* (2012) reported highest LER (1.719) in wheat-cowpea intercropping and lowest (1.46) in wheat mustard intercropping, while using different intercrop combinations (Table 4). Wasaya *et al*. (2013) also reported a clear increase of LER in wheat-fenugreek intercropping. Intercropped resulted the greater LER (1.78) than the mixed crop (1.66) and was found most effective for sustainable production in the rainfed areas for a higher net return.

Table 4. Intercropping of wheat with various legumes and non legumes.

Intercropping System	Row ratio	LER	Country	References
Wheat +Lentil	1:1	1.17	Bangladesh	Akter *et al.* (2004)
Wheat+Lentil	1:2	1.15	Bangladesh	Akter *et al.* (2004)
Wheat + Mustard	10:2	1.21	India	Singh and Gupta (1994)
Canola+Wheat	2:1	1.17	Pakistan	Ali *et al.* (2000)
Wheat+Mustard	1:1	1.46	Bangladesh	Khatun *et al.(* 2012)
Wheat+Cowpea	1:1	1.72	Bangladesh	Khatun *et al.* (2012)
Wheat+Linseed	1:1	1.48	Bangladesh	Khatun *et al.* (2012)
Wheat+corriander	1:1	1.54	Bangladesh	Khatun *et al.* (2012)
Wheat+Fenugreek	1:3	1.4	Pakistan	Wasaya *et al*. (2013)
Wheat+Maize	1:1	1.19	China	Gao *et al.* (2014)
Wheat+Brassica	2:1	1.78	Pakistan	Khan *et al.* (2014)

QUALITY CONSIDERATION: Lauk and Lauk (2005) concluded that legume cereal intercrop can result into higher grain and protein yield compared to respective sole crop of cereal. Hummel *et al.* (2009) conducted field experiments on canola/ wheat intercrop and described that crop quality characteristics of canola have variable response to intercropping system. Gooding *et al.* (2007) observed that intercropping wheat with grain legumes resulted in increase in N:S ratio upto 4% in wheat. There was also increased level of sodium dodecyl sulphate (SDS) and crude protein concentration (10 g kg^{-1}) in wheat. Lithourgidis and Dordas (2010) stated that intercropping of field bean with wheat improved forage dry matter, percentage of dry matter, crude protein, water soluble carbohydrates and neutral detergent fiber content compared with bean and wheat sole crop. Jensen (1996) stated that different legume-cereal intercropping significantly increased the grain nitrogen percentage in cereals crops.

Economic benefits: The maximum net income of Rs. 33647 ha^{-1} was obtained from wheat +3 rows of fenugreek against the minimum of Rs. 24791 ha^{-1} from sole cropping (Wasaya *et al*., 2013). Khatun *et al.* (2001) described that intercropping of potato with wheat grown with 2:5 gave higher LER, higher wheat equivalent yield, higher gross return and benefit cost ratio compared to 3:8 rows. Khanzada *et al.* (2000) stated that intercropping gave higher economic return than monoculture in case of wheat and safflower intercropped with alternate 4 row strips. Verma *et al.* (1997) reported maximum net return, benefit cost ratio and land equivalent ratio in case of intercropping of wheat and Indian mustard. Singh *et al.* (2000) carried out field experiment to study the yield and economics of intercropping of wheat with potato. They observed higher gross and net returns in wheat potato intercropping compared to sole wheat crop. Nazir *et al.* (2002) revealed that intercropping combination of sugarcane and wheat gave considerably higher net income ha^{-1} than sole crop. Munir *et al.* (2004) concluded that highest net income Rs. 10229 ha^{-1} with benefit cost ratio of 1.90 was observed in wheat grown in 100cm spaced 4 rows of wheat and intercropping of 3 rows of gram.

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