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Original Article

Strip intercropping system of chickpea, lentil and arugula crop as a promising option in spate irrigated area of Punjab, Pakistan

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Abstract

Studies were conducted to examine the effect of legumes and oilseed crop strips on inter-cropping properties and yield related parameters during the Rabi season 2017-18 at three selected locations in Mithawan Hill Torrent (spate) irrigated fields of Dera Ghazi Khan Punjab- Pakistan. The experiment was laid out in Randomized Complete Block Design (RCBD) having three replications. The sole strips of chickpea, arugula (locally called taramira), lentil were evaluated. Chickpea-arugula alternate strip, chickpea-lentil alternate strip, arugula-lentil alternate strip and chickpea-arugula- lentil alternate strip in combination were also investigated. Data was analyzed through ANOVA technique and differences among the treatments were tested using HSD Tukey's test. The obtained results shows that the Land Equivalent Ratio (LER) of sole chickpea was 0.97 and LER of strip intercropping was 1.79 which shows distinct advantage of strip intercropping. Relative Crowding Coefficient (RCC) value for chickpea, arugula and lentil were 25, 9.44 and 0.1, respectively when compared with the sole strip cropping. It shows that intercropping of chickpea and arugula were effective. Chickpea and arugula strip inter crop resulted in better LER and RCC with reasonable yield of both crops under the spate irrigated conditions of Mithawan hill torrent command area Dera Ghazi Khan Punjab (Pakistan). Area time equivalent ratio could not bring significant differences among the strip inter cropping treatments. Lentil could not succeed in strip inter cropping in spate irrigated situations of Mithawan hill torrent. The obtained results recorded maximum 1000 seed weight of chickpea (144.80 g) and arugula (4.72 g); seed yield of chickpea (800.16 kg ha^{-1}), arugula (433.14 kg ha^{-1}), respectively when both crops were grown in the form of separate sole strip. Hence for achieving maximum yield, the farmers of spate irrigated area of Mithawan hill torrent area should sow chickpea or arugula as a sole strip.

Keywords: Arugula, Chickpea, Inter cropping, Lentil, Mithawan hill torrent, Spate irrigated area, Strip cropping, Yield

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Introduction

A spate irrigation system use seasonal floods which is the second largest source of irrigation water from hill torrent after canal water in Pakistan (Ahmad et al., 2016). At sowing time variation in the rain fall may affect spate irrigation (Javed et al., 2007). A major portion of land of about 13.25 million hector, out of which hilly areas are 6.35 million ha and plains 6.9 million ha however, in spate irrigation annually cultivated land is 0.72 to 2.0 million ha, which marks about 9% of the total irrigated area of Pakistan in a year (Mirjat et al., 2011). The techniques used to conserve agriculture resources are zero tillage, crop cover, crop residue cover, site specific nutrient management, laser land leveler, crop rotation, integrated farming system, rain water harvesting, off season tillage and ploughing, contour farming and strip intercropping etc.

Cultivation of two or more crops on the same piece of land (Sarkar et al, 2000), at the same time in an organized manner for development of some or all the plant part (Elemo et al., 1990) is called intercropping. It is carried out in many parts of the world due to its relative advantages including higher stability of yield, higher efficiency of land and labor use (Klindt et al., 2007). In developing countries intercropping may have positive effect on the future food problems (Egbe, 2005). Most of the advantages of intercropping are obtained by application of legume species (Manjith et al., 2009).

Intercropping of oilseed crops with legumes can promote resource use efficiency compared to mono culture and improve the yield (Singh et al, 2010). It is performed in low input and low fertile soils of tropic regions (Sabaghpour et al., 2005). Among the crops, legumes have great ability in adaptation to cultivation pattern and can improve production capacity (Banik et al., 2006; Mahfouz and Migawer, 2004). Nazir et al., 1988 stated that intercropping of lentil *(Lens culinaris),* Sarson *(Brassica napus)* and chickpea *(Cicer arietinum)* decrease the yield of wheat over wheat cultivated in non-irrigated conditions. Henriet et al., (1997) explored that in Sudan savannah of Nigeria intercropping was the pre dominant system with millet, cowpea, sorghum, groundnut and millet. Legumes improve the nitrogen in the soil and enhance crop yield.

Chickpea (*Cicer arietinum* L.) and rapeseed (*Brassica napus* L.) are grown in single plus in mix cropping because of their different morphology, growth time and climatic requirements. Growing of mustard as an intercrop in chickpea is a common practice. If recommended ratio of chickpea with oilseeds like rapeseed-mustard for an area is adopted then farmers could utilize useful and available resources more efficiently and effectively on sustainable basis. In intercropping, production is commonly maximum than in alone cropping system (Lithourgidis et al., 2007; Dahmardeh et al., 2009).

The advantage of yield in intercropping mainly depend on the use of resources such as light, water and nutrients than alone crop (Liu et al., 2006). Nitrogen uptake increases upto 50 to 59% in intercropping of wheat-maize while in wheat-soybean increase in nitrogen is 19 to 23% (Zhang and Li, 2003). Barillot et al., (2014) found remarkably increased radiation productivity in intercropping of pea and wheat than that of sole crop of wheat. Eskandari and Ghanbari, 2011 evaluated intercropping effect of faba bean and wheat and explained better resource use on intercropping in terms of light capture, water and nutrient uptake in contrast to alone crop.

With the help of LER, the relationship between two crops, ability to use land and total production of intercropping system can be measured (Rashid et al., 2002). LER is commonly used to calculate the efficiency of land which is used in intercropping (Seran and Brintha, 2009). Studies on the effect of legumes and oilseeds grown in the form of alternate strip inter crops for effect on yield in spate irrigated areas are currently lacking worldwide. Hence the proposed study was designed to find out most viable feasible strip inter cropping and its impact on yield of chickpea, arugula (taramira), lentil in spate irrigated lands of Punjab (Pakistan).

Material and Methods

The experiment was laid in the Rabi season 2017-18 at three selected locations in Mithawan Hill Torrent spate irrigated fields of Dera Ghazi Khan that lies between latitude 29.731° N to 29.862°N and longitude 70.314°E to 70.487° E with altitude of about 2107 m above mean sea level. The experiment was carried out in RCBD with three replications.

Seed rate for lentil, chickpea and arugula (taramira) crops was 20, 90 and 5 kg ha^{-1} respectively. Seeds of lentil, chickpea and arugula (taramira) were line sown using seed drill, on October 08, 2017. The net plot size was 44 m×5.45 m. Lentil rows were kept 30 cm, chickpea 45 cm apart with spacing of plants at 23 cm

whereas arugula (taramira) having space between rows 45 cm with plants within row spaced at 15 cm. Urea, Diammonium phosphate and Sulphate of potash fertilizers were applied at the sowing time @ 17 kg Urea and 50 kg each of DAP and SOP per acre, respectively. Conserved soil moisture through rainfall received before and during the growing season was the only source of water available for crops to grow till maturity. All the other agronomic measures were kept regular and same for all the treatments.

Following treatments were applied in the experiment

S_1: Chickpea strip
S_2: Arugula (Taramira) strip
S_3: Lentil strip
S_4: Chickpea + Arugula (Taramira) alternate strip
S_5: Chickpea + Lentil alternate strip
S_6: Arugula (Taramira) + Lentil alternate strip
S_7: Chickpea+ Arugula (Taramira) + Lentil alternate strip

During the course of study following parameters were recorded.

Land equivalent ratio

LER was calculated to study intercropping competition and yield advantages in intercropping compared with sole cropping.

LER = LER (chickpea) + LER (intercrop)

Where,

$$\text{LER (chickpea)} = \frac{\text{Intercropped yield of chickpea}}{\text{Sole crop yield of chickpea}}$$

$$\text{LER (intercrop)} = \frac{\text{Intercropped yield of chickpea, arugula (taramira) and lentil}}{\text{sole crop yield of chickpea, arugula (taramira) and lentil}}$$

Relative crowding Co-efficient (RCC)

RCC plays a significant role in measuring the competition effect and benefits in intercropping. Relative crowding co-efficient (k) was measured by following formula (De Wit, 1960).

$$K_{ab} = \frac{Y_{ab} \_ Z_{ba}}{Y_{aa} - Y_{ab} - Z_{ab}}$$

Where,

K_{ab}= Relative crowding co-efficient for species a in polyculture with species b

Y_{ab}= Intercrop yield of crop "a" in polyculture with species b

Y_{aa}= Pure stand yield of crop "a"

Y_{bb}= Pure stand yield of crop "b"

Y_{ba}= Intercrop yield of crop "b'' in polyculture with species a;

Z_{ab}= ratio (%) of species a to species b in polyculture

Z_{ba}= ratio (%) of species b to species a in polyculture

1. Area-Time equivalent ratio (ATER)

The Hiebsch (1980) introduced to measure time period of the crop remained on land from planting to the harvest. This method is known as ATER. The formula used to calculate the ATER was

ATER = ATER (chickpea) + ATER (intercrop)

Where

$$\text{ATER (Chickpea)} = \text{LER (chickpea)} \times \frac{\text{Time taken by chickpea crop}}{\text{Duration of inter crops in days}}$$

$$\text{ATER (Intercrop)} = \text{LER (intercrop)} \times \frac{\text{Time taken by intercrop crop}}{\text{Duration of inter crops in days}}$$

2. 1000 seed weight (g)

From each treatment samples of seeds were taken. 1000 seeds were calculated and weighed on an electric balance and average was calculated.

3. Total dry biomass yield (kg ha^{-1})

After drying and before threshing, entire above ground plant biomass per plot was weighed and converted into kg ha^{-1}.

4. Seed yield (kg ha^{-1})

The harvested samples of chickpea, arugula (taramira) and lentil were sun dried and threshed manually. Seeds per plot were weighed and changed into kg ha^{-1}.

5. Harvest index (%)

It was noted for each plot for chickpea and arugula by applying the formula:

$$\text{HI \%} = \frac{\text{Economic yield (seed yield)}}{\text{Total Dry Biomass Yield (seed + straw)}} \times 100$$

Experimental layout

Resource Conservation through Strip Cropping of Chickpea, Taramira and Lentil in Spate Irrigate Area

R1	Chickpea Sole Strip	Sub path	Taramira (Arugula) Sole Strip	Sub path	Lentil Sole strip	Sub Path	Chickpea and Lentil Strip	Sub path	Chickpea and Taramira (Arugula) Strip	Sub path	Taramira (Arugula) and Lentil Strip	Sub Path	Chickpea+ Taramira (Arugula)+ Lentil Strip
Path													
R2	Chickpea Sole Strip	Sub path	Taramira (Arugula) Sole Strip	Sub path	Lentil Sole Strip	Sub Path	Chickpea and Lentil Strip	Sub path	Chickpea and Taramira (Arugula) strip	Sub path	Taramira (Arugula) and Lentil Strip	Sub Path	Chickpea+ Taramira (Arugula)+ Lentil Strip
Path													
R3	Chickpea Sole Strip	Sub path	Taramira (Arugula) Sole Strip	Sub path	Lentil Sole Strip	Sub Path	Chickpea and Lentil Strip	Sub path	Chickpea and Taramira (Arugula) Strip	Sub path	Taramira (Arugula) and lentil Strip	Sub Path	Chickpea+ Taramira (Arugula)+ Lentil Strip

Design: Randomized Complete Block Design
Replications: Three
Net Plot Size: 44 m x 5.45 m

Results and Discussion

The results from three locations could not vary significantly, hence the pooled data has been discussed.

Strip inter cropping component

The LER value obtained from the intercropping of three crops under test (i.e. chickpea, taramira and lentil) was 1.79 and in the sole strip inter cropping of chickpea, the LER value obtained was 0.97. It indicates that the yield obtained in intercropping chickpea with lentil and Arugula (taramira) resulted an overall increase in benefit of 1.79 % than the sole strip inter cropping of chickpea, arugula (taramira) or lentil (Lithourgidis et al., 2007; Dahmardeh et al., 2009) (Fig.1). Higher LER in intercropping treatments could be owing to improved land use (Banik, 1996 and Dhaka et al., 2014). It can be due to improved use of resources like light, water, nutrients and land etc (Banik et al., 2006 and Shehata et al., 2007). Khatun et al., (2012) also showed highest land equivalent ratio (1.719) in wheat and cowpea intercropping. The probable reason could be that in sole cropping low LER produced low yield than that from intercropping. Wasaya et al., (2013) reported greater LER (1.78) in wheat-fenugreek intercropping. Higher LER in chickpea-fennel intercropping as compared to sole crop was also reported (Awasthi et al., 2011).

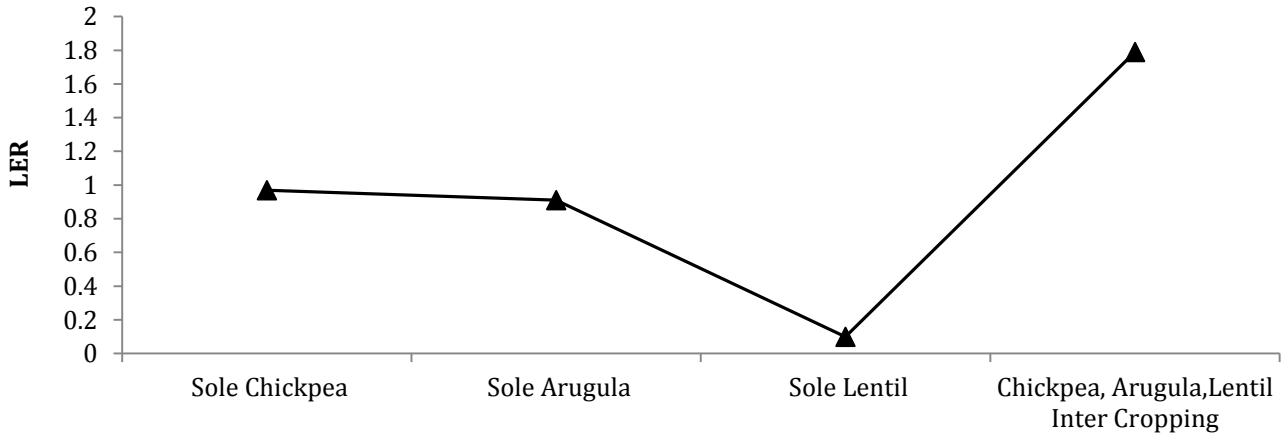

Fig. 1: Land Equivalent Ratio of sole and inter-cropping systems of chickpea, arugula (taramira) and lentil in spate irrigated areas.

Relative crowding co-efficient (RCC) play a significant role in determining the competition effect and advantage in intercropping. The RCC obtained for chickpea, arugula (taramira) and lentil was 25, 9.44 and 0.13, respectively (Fig. 2). Previous work also demonstrates higher RCC in intercropping setup than sole cropping system (Tanwar et al., 2011). The component crop with higher "K" value dominates and that with low "K" value is dominated. The expected reason could be that chickpea and arugula grow well together in intercropping system than with alternate strip-cropping of lentil. RCC indicated intercrop as dominant species in a crop mixture situation (Ahlawat et al., 2005). Jabbar et al., (2009) outcomes are quite in agreement and explained ricebean, cowpea and pigeonpea intercrops appeared to be dominant as they had higher values for "K"

To measure the time of component crop in inter cropping, the ATER was determined. The ATER produce more accurate yield advantages of inter crop than the sole crop. It consider the variations in the time taken by the component crop in an inter-cropping system. In present study, the value of area time equivalent ratio for all the treatments was calculated and found to be similar as for LER in the intercropping system. Though the harvesting time of chickpea and lentil could not differ significantly but it varied from arugula (taramira) crop which was harvested few days earlier than chickpea and lentil however this could not bring significant difference. Furthermore the similar values of ATER to LER could be attributed to same time of plantation in strip inter-crops of three crops under test i.e. chickpea, arugula (taramira) and lentil.

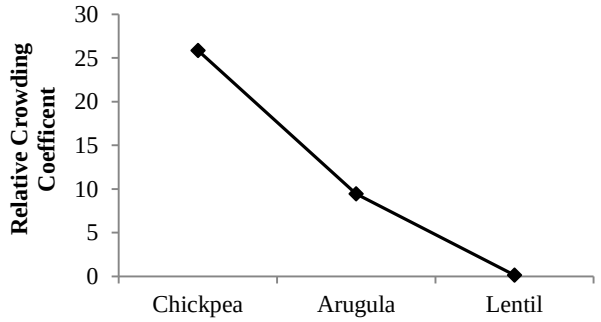

Fig. 2: Relative Crowding Coefficient of chickpea, arugula (taramira) and lentil strip inter-cropping systems in spate irrigated areas.

Yield components

Chickpea

Chickpea based strip intercrops resulted in significant differences among all the treatments employed for 1000 seed weight, total dry biomass yield and seed yield. The higher 1000 seed weight (144.80 g), maximum total dry biomass yield (3181.40 kg ha^{-1}), higher seed yield (800.16 kg ha^{-1}) and statistically highest harvest index (31.25%) for chickpea was calculated in the plots where chickpea was grown as a sole crop. The obtained results are contradictory to the findings of Lesoing and Francis (1999) who observed increase in seed weight in the edge rows of maize grown in strip cropping with soybeans. The similar results have also been reported by Ancha and Ahlawat (1990), who stated that the harvest index of sole pigeon pea was higher than pigeon pea and mung bean inter cropping.

The lowest total dry biomass yield (2559.10 kg ha^{-1}), statistically low seed yield (771.25 kg ha^{-1}) and significantly minimum harvest index (24.22%) of chickpea was noticed in plots where all the three crops under study i.e. chickpea, arugula (taramira) and lentil were grown in alternate strips (Table 1). It might be due to high competition among crop plants under study for light, water and nutrients. While the alternate strip of chickpea- arugula (taramira) or chickpea-lentil were intermediate for their effects on seed yield. The results obtained by Głowacka (2010) who stated decrease in the yield of spring wheat, maize and common bean in strip cropping are in consonance with our findings. The results obtained are contrary to the findings of Głowacka (2011) who stated that yield of maize, wheat and bean may be higher in strip cropping as compared to single-species crops. Use of cover crops (living mulch) in Norwegian spring cereal production system significantly improved grain yield by 16–22% (Brandsæter et al., 2012). The average yield of chickpea in spate irrigated system Mithawan hill torrent was 575.6 kg ha^{-1} (GOP, 2003) and 1991 kg ha^{-1} as reported by Ahmad et al., 2016. They further reported minimum seed yield for gram to be 618 kg ha^{-1}. The chickpea yield obtained in the study is significantly greater than the minimum reported. Furthermore, the relatively lower seed yield than the current reported average as given by Ahmad et al., 2016 is understandable because year 2017 was dry year with less rain received in the Mithawan hill torrent at study sites. Groundnut intercropped with cereals produced low pod yield due to lower groundnut plant density in intercropping system and presence of competition between the species (Trenbath, 1976).

Table 1: Effect of chickpea based strip intercrops on Yield attributes of chickpea

Treatments	1000 seed weight (g)	Total Dry Biomass Yield (kg ha^{-1})	Seed yield (kg ha^{-1})	Harvest index (%)
Chickpea Strip	144.80 A	3181.40 A	800.16 A	31.25 A
Chickpea and Arugula (Taramira) alternate Strip	133.27 B	2869.80B	787.73 B	28.76 B
Chickpea and Lentil alternate Strip	127.00 B	2741.20C	779.02 C	27.14 C
Chickpea, Arugula (Taramira) and Lentil alternate Strip	116.27 C	2559.10D	771.25 D	24.22 D
Tukey's HSD value	0.9683	100.19	5.2694	0.9388

Means followed by same letters do not differ significantly at P= 0.05

Arugula (Taramira)

Arugula (Taramira) based strip intercrops resulted in significant differences among the treatments employed. The results showed that the highest weight (4.72 g) of 1000 seeds of arugula (taramira), yield of seed was maximum (433.14 kg ha^{-1}) and harvest index was significantly higher (23.35 %) in those plots where the arugula (taramira) plants were grown as the alone strip. The statistically lowest seed index (4.50 g), seed yield (375.23 kg ha^{-1}) and lowest harvest index (20.27 %) was observed in the alternate strip of three crops viz chickpea- arugula (taramira)-lentil (Table 2). Alternate strip of arugula (taramira)-lentil also resulted in statistically lowest 1000 seed weight. Results of Lesoing and Francis (1999) i.e. higher weight of seed in edge rows of maize grown in strip cropping with soybean are contradictory to our findings. This can be attributed to differences in species used for inter-cropping. The results obtained are same to the results of Giri et al., (1980) who reported that intercropping of fast growing pearl millet reduced the growth or seed yield of pigeon pea. Similar results have also been reported by Ancha and Ahlawat (1990) who stated that harvest index of mung bean and pigeon pea intercropping system is low than the sole pigeon pea. Intercropping of brassica campestris var. toria could not perform well as compared to pea (Subedi, 1997).

Arugula (Taramira) based strip intercrops resulted in non-significant differences among all the treatments applied for total dry biomass yield. The results obtained by Lesoing and Francis, 1999 favor this outcome who stated that the results of strip cropping on the yield of maize are undetermined.

Lack of competition with companion crop, more uniform conditions in the habitat with more number of plants explains why sole crop yield of chickpea and arugula is higher than in intercrops (Grime, 1977).

Table 2: Effect of Arugula (Taramira) based strip intercrops on Yield attributes of Arugula (Taramira)

Treatments	1000 seed weight (g)	Seed yield (kg ha^{-1})	Total Dry Biomass Yield (Kg ha^{-1})	Harvest index (%)
Arugula (Taramira) strip	4.72 A	433.14 A	1854.70 ns	23.35 A
Chickpea + Arugula (Taramira) alternate strips	4.66 AB	414.36 B	1851.3 0	22.53 B
Arugula (Taramira) + Lentil alternate strips	4.59 BC	395.46 C	1851.1 0	21.37 C
Chickpea+ Arugula (Taramira) + Lentil alternate strips	4.50 C	375.23 D	1838.4 0	20.27 D
Tukey's HSD value	0.1073	5.9414	50.523	0.6916

Means followed by same letters do not differ significantly at P= 0.

Higher 1000 seed weight in sole cropping systems compared to intercropping systems can be attributed to lesser resources competition (Shehata et al., 2007). It appears that higher grain and total dry biomass yield increased in connection with increased number of pods per plant in sole chickpea (Torkaman et al., 2018) helping improved growth in sole cropping than intercropping systems (Wahua, 1983). Likewise Getachew et al. (2006) reported lower biological yield

of faba bean in intercropping with barley than sole crop owing to more competition between species. Abundant solar radiation interception in sole cropping (Stirling et al., 1990) also would have favored more photosynthates accumulation in seeds resulting in higher seed weight and seed yield in chickpea and arugula.

Lentil

Significant differences were observed in lentil based strip intercropping. However, the overall seed yield per plant obtained was almost negligible. The results showed that higher yield of seed per plant (0.17 g) was produced from the strip where lentil plants were grown as a sole crop. The yield was statistically lowest (0.147 g) in the alternate strip of chickpea- arugula (taramira)-lentil (Table 3). Poor grain yield of lentil in intercropping with crops like wheat has earlier been reported (Banik et al., 2006). Almost the same result was obtained by Tiwari et al., (1992) who stated that seed and straw yields of Indian mustard was not affected significantly by Indian mustard paired row (30/90 cm) + lentil (2 rows) intercropping. Whereas lentil seed and straw yields were reduced significantly under intercropping system. The reduction in lentil yield was mostly due to reduced population of plant per unit area and lower values of growth parameters (Tiwari et al., 1992). Non availability of water at flowering stage could have significantly hampered the seed development and might have resulted in significantly reduced assimilates accumulation in seed. Intercrop success bases on relative density of component crops (Ghanbari and Lee, 2003).

Intercropping system of chickpea, arugula (taramira) and lentil may not be the good combination of intercropping most likely due to differences among plant architecture, resource competitiveness and differential response to limited soil moisture available. Among intercropping systems, lentil could not succeed in spate irrigated conditions of Mithawan hill torrent area Dera Ghazi Khan. Hence, total economical yield of sole and intercropped chickpea and arugula has been presented in Figure 3.

Table 3: Effect of Lentil based strip intercrops on Seed Yield per Plant of Lentil

Treatments	Seed Yield per Plant (g)
Lentil strip	0.17 A
Chickpea + Lentil alternate strip	0.16 B
Arugula (Taramira) + Lentil alternate strip	0.15 BC
Chickpea+ Arugula (Taramira) + Lentil alternate strip	0.14 C
Tukey's HSD value	0.0125

Means followed by same letters do not differ significantly at P= 0.05

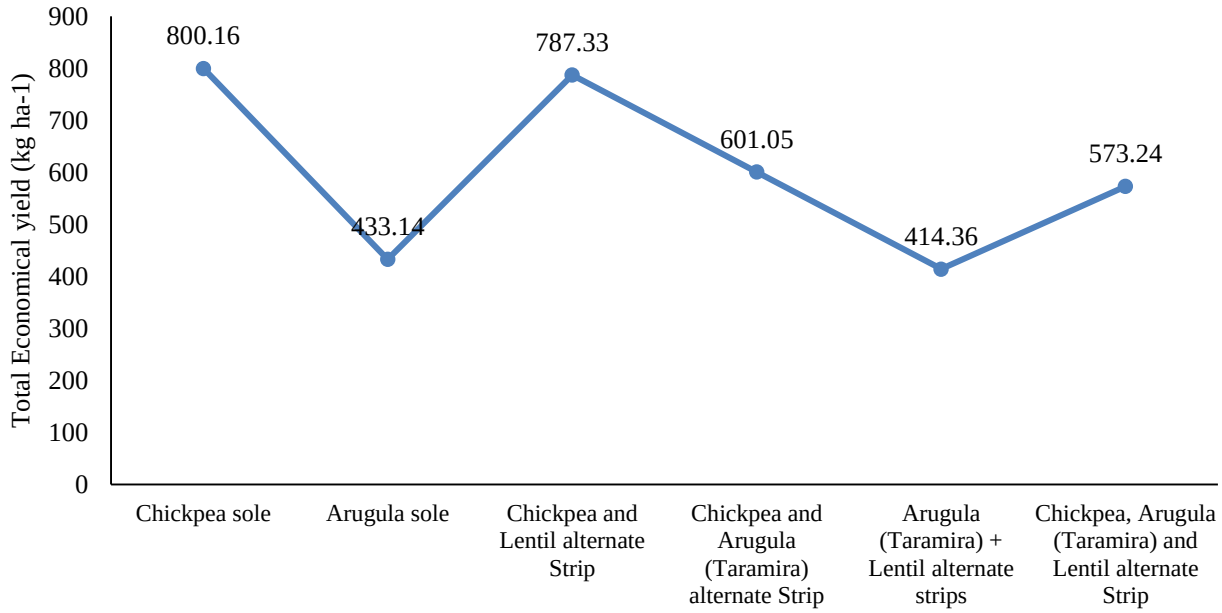

Fig. 3. Total economical yield of chickpea, arugula (taramira) and lentil strip inter-cropping systems in spate irrigated areas.

Conclusion

From the current study it can be concluded that chickpea- arugula (taramira) alternate strip intercropping appeared to be better feasible strip intercropping option giving higher land equivalent ratio and relative crowding coefficient by maximizing resource use efficiencies. It is worth mentioning that lentil could not establish under the agro normals of mithawan spate irrigated systems under low soil moisture regimes therefore could not produce significant yield. Sole strip cropping of chickpea and arugula (taramira) appeared to be better for attaining higher yield than other strip intercropping systems. Therefore, farmers of hill torrent affected area of Mithawan command area Dera Ghazi Khan, Punjab (Pakistan) should adopt sole strip cropping of chickpea or arugula for getting higher crop yield.

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Contribution of Authors

Amin J: Literature Search, Data Collection, Literature Review
Mubeen K: Conceived Idea, Designed Research Methodology
Ahmad M: Data Interpretation
Aziz M: Statistical Analysis
Arif M: Manuscript final reading and approval

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