Production potential and economic feasibility of blackgram (*Vigna mungo* L.) + sesame (*Sesamum indicum* L.) intercropping under rainfed ecosystems of Jammu

Sushil Kumar Suri[1], M.C. Dwivedi, R. Puniya[1], Ashu Sharma[1],
Rakesh Kumar[1], J. Kumar[2], A.P. Rai[3], V.B. Singh[4]

10.18805/LR-3969

ABSTRACT

An investigation was conducted at Advance Centre for Rainfed Agriculture, Rakh Dhiansar, SKUAST-Jammu during *kharif* season of 2015. The experiment was laid out in randomized block design with three replications. The nine treatments *viz*. sole blackgram, sole sesame, blackgram + sesame (1 row of sesame in 2 rows of blackgram) additive series, blackgram + sesame (1:1) replacement series, black + sesame (3:1) replacement series, blackgram + sesame (5:1) replacement series, blackgram + sesame (1:3) replacement series, blackgram + sesame (1:5) replacement series and blackgram + sesame (seed mix) were taken for study. The soil of experimental field was sandy loam in texture, slightly acidic in reaction, low in organic carbon and available nitrogen and medium in available phosphorus and potassium. The experimental results revealed that among the different intercropping systems blackgram + sesame (5:1) replacement series recorded highest blackgram equivalent yield (BEY) 7.01 q ha^{-1} which was statistically at par with blackgram + sesame (3:1) replacement series, blackgram + sesame (1:1) replacement series and blackgram + sesame (1:1) additive series and significantly higher than other intercropping systems. Also blackgram + sesamum (5:1) row ratio gave highest value of land equivalent ratio, aggressivity, area time equivalent ratio, net returns, B:C ratio, energy output, energy use efficiency, net energy return, energy productivity and energy intensity followed by blackgram + sesame (3:1) replacement series.

Key words: Blackgram, Economics, Energy, Equivalent yield, Intercropping, Sesame.

INTRODUCTION

The rainfed area at the global level comprises of about 79% of the total cropped area contributing two third of the global food production (Rockstrom, 2007). India being the seventh largest country in the world encompasses the second largest arable land area after USA. About 58% of the country's population directly and 10% of population indirectly are dependent on agriculture and its allied sectors for generation of their livelihood (Purkayastha, 2009). Rainfed agriculture in India has been practiced since time immemorial and its area currently constitutes 55% of net sown area of the country. Two third of the livestock and 40% of human population of the country live in rainfed areas (Anonymous, 2014). In view of shrinkage resources particularly arable land area, irrigation water and energy, the only option left is to increase the production per unit area/time. Therefore, the need for introducing new technologies for increasing sustainable yields in rainfed areas. Pulse crops being legume in nature are endowed with unique ability for biological nitrogen fixation, deeper root system, low water requirement, capacity to withstand drought, owing to these inherent peculiarities they are considered to be important rainfed crops of the country. Simultaneously, inclusion of pulses can be considered as an attempt to enhance the pulse production from rainfed areas by introducing them as intercrops. Scientific approach of intercropping increases the productivity per unit area per unit time under a situation where two crops are grown in intercropping at a certain proportion and row ratio. In Jammu and Kashmir, total area under pulses and oilseed is 27.44 and 64.53 thousand ha with a production of 144 and 533 thousand quintals, respectively (Anonymous, 2014). Blackgram and sesame

Division of Agronomy, Research Farm, Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha-180 009, Jammu and Kashmir, India.
[1]Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu-180 009, Jammu and Kashmir, India.
[2]ACRA, Dhainsar, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu-180 009, Jammu and Kashmir, India.
[3]Division of Soil Science, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu-180 009, Jammu and Kashmir, India.
[4]Division of Plant Pathology, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu-180 009, Jammu and Kashmir, India.

Corresponding Author: M.C. Dwivedi, Division of Agronomy, Research Farm, Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha-180 009, Jammu and Kashmir, India.
Email: drmaheshagron@gmail.com

How to cite this article: Suri, S.K., Dwivedi, M.C., Puniya, R., Sharma, A., Kumar, R., Kumar, J., Rai, A.P. and Singh, V.B. (2020). Production potential and economic feasibility of blackgram (*Vigna mungo* L.) + sesame (*Sesamum indicum* L.) intercropping under rainfed ecosystems of Jammu. Legume Research. 43(3): 370-377.

Submitted: 25-11-2017 **Accepted:** 27-04-2019 **Published:** 04-07-2019

are mainly grown as sole crops in Jammu region. It is possible to grow these crops in intercrops due to their diverse morphology, growth rhythm and similar climatic requirements. Intercropping increases the cropping intensity, productivity and profitability through optimal utilization of soil, water, nutrients and sunlight in time and space. It fetches high net returns, raises farmer's income, standard of living and generates more employment opportunities. Thus, there is a need for identification of suitable row ratio for rainfed belt of Jammu region. Since there is no information available on performance of blackgram+sesame intercropping under rainfed belt of Jammu region, hence the present study was carried out.

MATERIALS AND METHODS

The field experiment was conducted at Advance Centre for Rainfed Agriculture of Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, Chatha, Jammu and Kashmir, India during *Kharif* 2015. Geographically, the experimental site is located at 32° 39′ N latitude and 74° 58′ E longitude at an elevation of 332 meters above the mean sea level in the Shivalik foothill plains of North-Western Himalayas.The soil of the experimental site was sandy loam in texture (Sand 71.6%, Silt 17.0% and Clay 11.4%), slightly acidic in reaction with pH of 6.86, EC of 0.21 dS m^{-1}, low in organic carbon (0.34%) and available nitrogen (175.27 kg ha^{-1}) but medium phosphorus (14.73 kg ha^{-1}) and potassium (112.29 kg ha^{-1}). The experiment was laid out in randomized block design with three replications having nine treatments *viz*. sole blackgram, sole sesame, blackgram + sesame (1 row of sesame in 2 rows of blackgram) additive series, blackgram + sesame (1:1) replacement series, black + sesame (3:1) replacement series, blackgram + sesame (5:1) replacement series, blackgram + sesame (1:3) replacement series, blackgram + sesame (1:5) replacement series and blackgram + sesame (seed mix). The recommended nutrients of blackgram @ 95 kg ha^{-1} of di-ammonium phosphate and for sesame @ 35 kg ha^{-1} of urea and 22 kg ha^{-1} of di-ammonium phosphate were applied as basal application at the time of sowing in lines below the seed.

A seed rate of 20 and 2.5 kg ha^{-1} for blackgram and sesame, respectively were used in their sole plots, respectively. The seeds of blackgram and sesame were sown on 20th July in furrows by *kera* method at row to row distance of 30 cm for both the crops. After 15 DAS the plant were thinned out within rows at a distance of 10 and 15 cm for blackgram and sesame, respectively. For all the growth and development studies during the crop growth period, five plants were selected randomly and tagged in each plot. The growth parameters such as plant height and dry matter accumulation were recorded at 60 days after sowing (DAS). Yield and yield attributing characters were determined using standard procedures, yield was expressed as q ha^{-1}. After harvest of the crops individual soil samples from all the plots were taken for determination of pH, EC, organic carbon, available nitrogen, phosphorus and potassium. The yield of sesame crop was converted into Blackgram equivalent yield based on price of the produce as mentioned below:

$$\text{Blackgram equivalent yield} = \sum_{i=1}^{n} (y_i + e_i)$$

Where,

y_i = Economic yield of i^{th} crop i.e Blackgram.

Equivalent Factor (e_i) =

$$\frac{\text{Yield of Sesame} \times \text{sale price of Sesame}}{\text{Sale price of Blackgram crop}}$$

LER was calculated as per the formula given by Willey (1979):

$$\text{LER} = (Ya/Sa) + (Yb/Sb)$$

Where,

Ya and Yb are yields of individual crops in mixture.

Sa and Sb are yield of individual crops in pure stand.

Area time equivalent ratio **(**ATER) was calculated as per the formula suggested by Willey (1979):

$$\text{ATER} = \frac{(\text{Li}t\text{ j} + \text{Lj}t\text{ i})}{\text{T}}$$

Where

L_i and L_j are relative yields of partial LER's of component i and j crops.

t_i and t_j are the duration (days) for crops i and j and T is the duration (days) of whole intercrop system.

Aggressivity (A) was calculated by using a formula (Willey, 1979) as given below:

$$\text{Aab} = \frac{\text{Mixture yield of 'A'}}{\text{Expected yield of 'A'}} - \frac{\text{Mixture yield of 'B'}}{\text{Expected yield of 'B'}}$$

$$\text{Aab} = \frac{\text{Yab}}{\text{Yaa} \times \text{Zab}} - \frac{\text{Yba}}{\text{Ybb} \times \text{Zba}}$$

Where,

Yaa is the yield component 'a' as sole crop.

Ybb is the yield component 'b' as sole crop.

Yab is yield component 'a' as intercrop grown in combination in the component 'b'.

Yba is yield of component 'b' as intercrop grown in combi- -nation with component 'a'.

Zab is the sown proportion of component 'a' in combination with 'b'.

Zba is the sown proportion of component 'b' in combination with 'a'.

The energy use efficiency, net energy return, energy productivity, specific energy and energy intensity were calculated by the formula:

Energy use efficiency (Output/Input ratio) =

$$\frac{\text{Output energy (MJ ha}^{-1})}{\text{Input energy (MJ ha}^{-1})}$$

Net energy return (MJ ha^{-1}) =

$$\text{Output energy} - \text{Input energy}$$

Energy productivity (kg MJ^{-1}) =

$$\frac{\text{Blackgram equivalent yield (kg ha}^{-1})}{\text{Energy Input (MJ ha}^{-1})}$$

Specific energy (MJ kg^{-1}) =

$$\frac{\text{Energy Input (MJ ha}^{-1})}{\text{Blackgram equivalent yield (kg ha}^{-1})}$$

Energy intensity (MJ $Rs.^{-1}$) =

$$\frac{\text{Energy Output (MJ ha}^{-1})}{\text{Cost of cultivation (Rs. ha}^{-1})}$$

The amounts of inputs were calculated per hectare basis and then, these data were multiplied with their coefficient of energy equivalents to determine the energy input/output based on previous studies (Table 1). All the data obtained were statistically analyzed using the *F*-test (Gomez and Gomez, 1984). Critical difference (CD) values at *P*=0.05 were used to determine the significance of differences between mean values of treatments.

RESULTS AND DISCUSSION

Growth characteristics

The differences in plant height and dry matter accumulation of blackgram due to different intercropping systems were found to be significant at 60 DAS (Table 2). The higher plant height (45.80 cm) and dry matter accumulation (7.03 g $plant^{-1}$) were recorded under sole blackgram, which was statistically at par with blackgram + sesame 5:1 replacement series, blackgram + sesame 3:1 replacement series, blackgram + sesame 1:1 replacement series and remain significantly superior over all other treatments. However, the lowest plant height and dry matter accumulation of blackgram were recorded in blackgram + sesame additive series. Significant changes in plant height and dry matter accumulation might have occurred due to competitiveness of plants for various essentials. The reduced competition for light, nutrients and other essentials under sole blackgram which probably might have led to increased height. Chhetri *et al*. (2015) also reported that there was significant reduction in plant height of blackgram when they were grown with sesame in an intercropping system as compared to their sole treatment.

The different intercropping systems showed significant difference in plant height and dry matter accumulation of sesame at 60 DAS (Table 2). Among the different intercropping systems highest plant height and dry matter accumulation to the tune of 107.73 cm 18.93 g $plant^{-1}$, respectively were observed in blackgram + sesame 5:1 replacement series, which was statistically at par with blackgram + sesame 3:1 replacement series, sole sesame, blackgram + sesame 1:1 replacement series, blackgram + sesame 1:3 replacement series and blackgram + sesame 1:5 replacement series of intercropping system but significantly superior over blackgram + sesame seed mix series and blackgram + sesame additive series. However,

Table 1: Energy equivalents for inputs in crop production.

Particulars	Unit	Equivalent energy (MJ $unit^{-1}$)	Source
Land preparation (2 harrowing + 1 planking)	Hours	332	Binnings *et al.* (1983)
Seed (Blackgram)	kg	13.96	Gopalan *et al.* (1978)
Seed (Sesame)	kg	15.20	Akpinar *et al.* (2009)
Human power	Mandays	1.96	Erdal *et al.* (2007)
Nitrogen (N)	kg	32.2	Hulsbergen *et al.* (2001)
Phosphorus (P_2O_5)	kg	15.8	Hulsbergen *et al.* (2001)
Herbicides	L	238	Green (1987)
Blackgram seed yield	kg	13.96	Gopalan *et al.* (1978)

Table 2: Effect of different intercropping systems on the plant height and plant dry matter of blackgram and sesame .

Treatment	Plant height at 60 DAS (cm)		Plant dry matter at 60 DAS (g $plant^{-1}$)	
	Blackgram	Sesame	Blackgram	Sesame
Sole Blackgram	45.80		7.03	
Sole Sesame		105.4		16.54
Blackgram + Sesame (additive series)	39.10	93.65	4.84	11.09
Blackgram + Sesame 1:1 (replacement series)	43.30	103.73	6.72	17.85
Blackgram + Sesame 3:1 (replacement series)	45.35	105.60	6.87	17.98
Blackgram + Sesame 5:1 (replacement series)	45.70	107.73	7.02	18.93
Blackgram + Sesame 1:3 (replacement series)	41.20	103.60	5.92	16.42
Blackgram + Sesame 1:5 (replacement series)	40.90	102.53	5.44	16.22
Blackgram + Sesame (seed mix)	40.51	98.23	5.04	16.22
SEm (±)	1.21	2.31	0.27	0.91
CD (P= 0.05)	3.68	7.04	0.83	2.76

the lowest plant height (93.65 cm) and dry matter accumulation (11.09 g plant^{-1}) were recorded with blackgram + sesame additive series. It was probably due to more space and nutrients available for growth and development of sesame, which led to higher photosynthesis owing to greater exposure of sesame plants to sunlight. It might also be due to conducive environment created by main crop (blackgram) as it fixed atmospheric nitrogen and increased its availability in soil which might have also been utilized partly by sesame plants for better growth and development and ultimately increased the growth characteristics. Similar results were also reported by Meena *et al.* (2008) in intercropping of sesame and cluster bean.

Yield attributes and yield

The intercropping of sesame had significant effect on yield attributes (pods plant^{-1} and seeds pod^{-1}) of blackgram. A comparison of yield attributing characters of the different blackgram based intercropping systems showed that the sole crop of blackgram recorded highest plants m^{-2} (30.6) followed by additive series treatment (Table 3). Higher number of pods plant^{-1}, seeds pod^{-1} and 1000-seed weight of sole stand of blackgram being statistically similar with blackgram + sesame replacement series of 5:1, 3:1, 1:1 and 1:3 row ratio but superior to blackgram + sesame 1:5 replacement series, blackgram + sesame additive series and seed mix series of blackgram + sesame intercropping. Similar results of increasing yield attributes were also reported by Sarkar *et al.*(2000). The data given in Table 4 revealed that blackgram in sole recorded highest seed and stover yield (5.88 q ha^{-1}) and (18.81 q ha^{-1}) and was followed by blackgram + sesame replacement series of 5:1 row ratio. Whereas, lowest seed and stover yield was obtained in blackgram + sesame 1:5 replacement series. The higher seed and stover yield of blackgram sole and 1:5 replacement series might have happened due to higher plant population as compared to other treatments. The reduction in seed and stover yields of blackgram in all intercropping systems over sole blackgram was primarily due to low plant population of blackgram in intercropping treatments. Reduction in yield of main crop blackgram might also be due to shading effect of sesame (component crop) on blackgram. These results are in close conformity with those of Tripathi *et al.* (2005) who reported significant reduction in yield of chickpea when grown in association with mustard. The blackgram seed yield increases with increase in pods plant^{-1} and 1000 seed weight of blackgram (Fig 1a and b).

A comparison of yield attributing characters of different intercropping treatments showed that the blackgram + sesame in 5:1 row ratio recorded highest capsule plant^{-1}, seeds capsule^{-1} and 1000-seed weight of sesame which was at par with blackgram + sesame 3:1 replacement series, blackgram + sesame 1:1 replacement series, blackgram + sesame 1:3 replacement series and blackgram + sesame 1:5 replacement series (Table 3). It was probably due to more space and nutrients available for growth and development of sesame, which led to higher photosynthesis owing to greater exposure of sesame plants to sunlight and also be due to conducive environment created by main crop (blackgram) as it fixed atmospheric nitrogen and increased its availability in soil which might have also been utilized partly by sesame plants for better growth, development and yield attributes. Similar results were also reported by Meena *et al.,* (2008) in intercropping of blackgram and sesame. The data presented in Table 4 revealed that among the different intercropping systems, the sole planting of sesame gave

Table 3: Effect of different intercropping systems on yield attributes of blackgram and sesame.

Treatment	No. of plants m^{-2}		No. of pods/capsules plant^{-1}		No. of seeds pod^{-1}/ capsule^{-1}		1000 seed weight (g)	
	Blackgram	Sesame	Blackgram	Sesame	Blackgram	Sesame	Blackgram	Sesame
Sole Blackgram	30.6		17.54		5.10		29.94	
Sole Sesame		21.1		25.20		40.44		2.34
Blackgram + Sesame (additive series)	29.2	17.7	14.32	20.48	4.25	34.33	24.77	2.08
Blackgram + Sesame 1:1 (replacement series)	14.8	10.3	16.08	25.69	4.86	42.14	28.71	2.40
Blackgram + Sesame 3:1 (replacement series)	22.7	5.5	16.83	26.12	4.91	42.72	29.15	2.44
Blackgram + Sesame 5:1 (replacement series)	25.8	3.69	17.12	27.21	5.00	43.77	29.52	2.48
Blackgram + Sesame 1:3 (replacement series)	7.2	15.0	15.72	25.12	4.69	40.47	27.41	2.38
Blackgram + Sesame 1:5 (replacement series)	4.8	16.2	15.22	25.04	4.39	40.17	26.59	2.35
Blackgram + Sesame (seed mix)	19.8	14.0	14.65	21.78	4.33	36.09	25.44	2.09
SEm (±)			0.61	0.83	0.16	1.24	0.87	0.11
CD (*P= 0.05*)			1.85	2.52	0.52	3.78	2.64	0.35

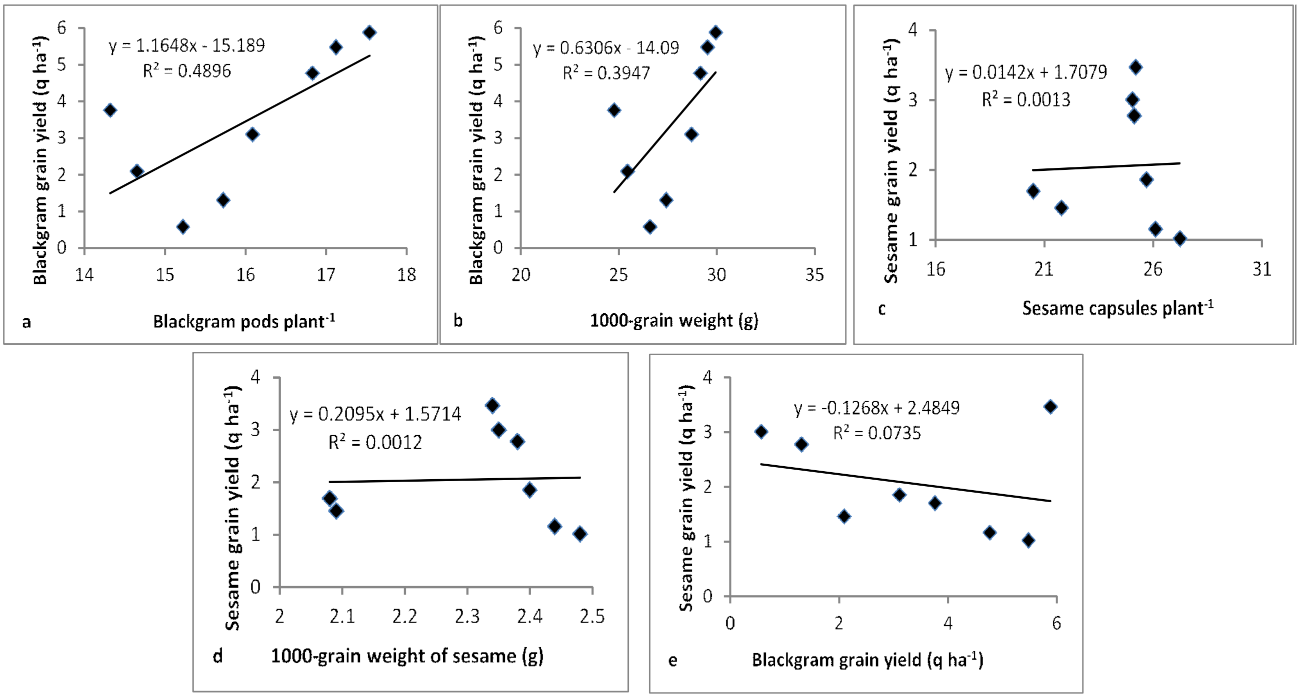

Fig 1: Yield and yield attributes of blackgram and sesame of crops (a= blackgram yield and pods plant^{-1}, b= blackgram yield and 1000 seed weight, c=sesame yield and capsules plant^{-1}, d=sesame yield and 1000 seed weight, e= sesame yield and blackgram yield).

Table 4: Effect of different intercropping systems on seed and stover yield of blackgram and sesame along with blackgram equivalent yield and relative economics of blackgram and sesame.

Treatment	Blackgram (q ha^{-1})		Sesame (q ha^{-1})		Blackgram equivalent yield (q ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B: C ratio
	Seed yield	Stover yield	Seed yield	Stover yield				
Sole Blackgram	5.88	18.81	-	-	5.88	14522	15878	1.09
Sole Sesame			3.47	15.84	5.20	12215	11285	0.92
Blackgram + Sesame (additive series)	3.76	11.72	1.70	7.12	6.31	16885	13965	0.82
Blackgram + Sesame 1:1 (replacement series)	3.11	10.15	1.86	8.96	5.90	13540	15060	1.11
Blackgram + Sesame 3:1 (replacement series)	4.77	15.32	1.16	5.62	6.51	14086	18344	1.31
Blackgram + Sesame 5:1 (replacement series)	5.48	17.39	1.02	4.92	7.01	14522	20628	1.43
Blackgram + Sesame 1:3 (replacement series)	1.31	4.01	2.78	13.23	5.48	12897	12503	0.96
Blackgram + Sesame 1:5 (replacement series)	0.57	1.75	3.01	14.09	5.08	12600	10600	0.84
Blackgram + Sesame (seed mix)	2.09	6.83	1.46	7.32	4.28	13540	7060	0.52
SEm (±)	-				0.36			
CD (*P= 0.05*)					1.11			

significantly higher seed (3.47 q ha^{-1}) and stick yields (15.84 q ha^{-1}) followed by blackgram + sesame in 1:5 series as compared to other planting in different row ratios. This was primarily due to higher plant population per unit area in sole sesame. The higher yields under pure stand were also reported by Tiwari *et al.* (1994) in sesame, greengram and soybean and Sarkar and Sanyal (2000) in sesame, groundnut and sunflower as compared to their yields under intercropping systems. The sesame seed yield increases with increase in capsules plant^{-1} and 1000 seed weight of sesame (Fig 1c and d).

In blackgram and sesame intercropping system, sesame yield decreases with increase in blackgram yield (Fig 1e). Blackgram equivalent yield (BEY) significantly influenced by different intercropping systems (Table 4). However, among the different intercropping systems, blackgram + sesame 5:1 replacement series recorded significantly higher blackgram equivalent yield which was at par with blackgram + sesame 3:1 replacement series, blackgram + sesame additive series and blackgram + sesame 1:1 replacement series. The lowest blackgram equivalent yield was calculated in seed mix series blackgram + sesame intercropping system. This increase in blackgram equivalent yield of intercropping systems over sole blackgram system was mainly due to beneficial effects of intercropping with differential yield behaviours of the crops which ensured higher total productivity and profitability due to additional yield advantage of intercrop yield. Prajapat *et al*. (2012) also found higher values of mungbean equivalent yield in mungbean+sesame intercropping as compared to sole sesame. Tripathi *et al*. (2005) and Ahlawat *et al*. (2005) also recorded similar findings in respect of chickpea equivalent yield in chickpea+mustard intercropping system.

Intercropping indices

All the intercropping treatments resulted in significantly higher LER as compared to the sole crop (Table 5). Blackgram + sesame in 5:1 replacement series gave the highest LER upto (1.22) followed by blackgram + sesame 3:1 replacement series (1.14) and blackgram + sesame additive series (1.11) and found biologically more efficient as compared to other intercropping systems. This yield advantage due to intercropping could possibly be attributed to the combined effects of better utilization of resources by component crops having different rooting patterns, differential canopy distribution and efficient light interception by their green surfaces and differential nutrient extraction from different soil depths in intercropping system. Whereas, lowest value 0.78 of LER was realized in blackgram + sesame (seed mix). The area-time equivalent ratio (ATER) is the performance of each intercrop component by the length of time required to grow and harvest it. Blackgram + sesame in 5:1 replacement series recorded higher value of ATER (1.14) as compared to other replacement and additive treatment (Table 5). This might have happened due to optimum utilization of land resources with respect to time 5:1 replacement series treatment. These results were in accordance with the findings of Sinha *et al.* (1999) and Tripathi *et al.* (2010).The competitive ability of the component crops in an intercropping system is determined by its aggressivity value. The zero value of aggressivity indicates that component crops are equally competitive. For any other situation, both crops will have the same numerical value but the sign of the dominant species will be positive and that of dominated negative. Among the intercropping treatments, positive value of 0.66, 0.46, 0.26, 0.17 0.13 and 0.02 were recorded in sesame crop of replacement series of 5:1, 1:5, 3:1, 1:3, seed mix and 1:1 blackgram + sesame intercropping systems, respectively, which denotes in all these treatments sesame crop was dominant on blackgram (Table 5). This probably happened due to early suppressive ability of the fast growing high foliage sesame crop along with its better ability to intercept light and also utilize soil resources which enabled it to become more efficient in resource utilization as compared to blackgram crop. Negative value of -0.29 was recorded in crop in additive treatment which showed that in this case blackgram crop was dominant on sesame crop. Among the intercropping treatments, blackgram + sesame 5:1 replacement series registered highest net returns and B: C ratio followed by blackgram + sesame 3:1 replacement series. However, the seed mix series of blackgram + sesame intercropping system registered lowest net returns (Table 4).

Table 5: Effect of different intercropping systems on performance of indices.

Treatment	Indices		
	LER	Aggressivity	ATER
Sole Blackgram	1.00		1.00
Sole Sesame	1.00		1.00
Blackgram + Sesame (additive series)	1.11	- 0.29	1.12
Blackgram + Sesame 1:1 (replacement series)	1.05	+ 0.02	1.01
Blackgram + Sesame 3:1 (replacement series)	1.14	+ 0.26	1.07
Blackgram + Sesame 5:1 (replacement series)	1.22	+ 0.66	1.14
Blackgram + Sesame 1:3 (replacement series)	1.02	+ 0.17	1.00
Blackgram + Sesame 1:5 (replacement series)	0.96	+ 0.46	0.94
Blackgram + Sesame (seed mix)	0.78	+ 0.13	0.73

Soil fertility changes

The soil chemical parameters *viz.* pH, EC and organic carbon and availability of nutrients (N, P and K) in soil after harvesting of blackgram and component crop (sesame) were not influenced significantly by different intercropping systems (Table 6). However, values of available N, P and K in soil parameters were observed to be higher in additive series treatment followed by sole blackgram and different replacement series and in sole sesame. Similar findings were also reported by Khola *et al.* (2000).

Energy

Energy in agriculture is important in terms of crop production and agro processing for value adding (Karimi *et. al.,* 2008). The relation between agriculture and energy is very close. Agriculture itself is an energy user and energy supplier in the form of bio-energy. At present, productivity and profitability of agriculture depends on energy consumption (Alam *et. al.,* 2005). Data presented in Table 7 revealed that among the different treatments energy output (MJ ha^{-1}),

Table 6: Effect of different intercropping systems on electrical conductivity (EC), organic carbon (OC), available N, P and K after harvest of crop.

Treatment	EC (ds m^{-1})	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Sole Blackgram	0.21	0.35	174.2	15.8	111.2
Sole Sesame	0.20	0.34	174.3	15.3	110.7
Blackgram + Sesame (additive series)	0.22	0.35	177.8	17.5	113.3
Blackgram + Sesame 1:1 (replacement series)	0.21	0.35	175.3	16.5	112.2
Blackgram + Sesame 3:1 (replacement series)	0.20	0.35	175.7	16.2	112.9
Blackgram + Sesame 5:1 (replacement series)	0.21	0.34	175.2	15.8	111.9
Blackgram + Sesame 1:3 (replacement series)	0.21	0.34	174.3	15.3	111.4
Blackgram + Sesame 1:5 (replacement series)	0.21	0.34	174.2	15.8	111.3
Blackgram + Sesame (seed mix)	0.22	0.34	174.4	16.4	112.3
SEm (±)	0.01	0.01	1.32	0.40	0.97
CD (*P= 0.05*)	NS	NS	NS	NS	NS

Table 7: Energy use patterns of blackgram and sesame intercropping system as influenced by different treatments.

Treatment	Energy input (MJ ha^{-1})	Energy output (MJ ha^{-1})	Energy use efficiency (MJ/MJ)	Net energy return (MJ ha^{-1})	Energy productivity (kg MJ^{-1})	Specific energy (MJ kg^{-1})	Energy intensity (MJ $Rs.^{-1}$)
Sole Blackgram	5189.14	8208.48	1.58	3019.34	0.11	8.83	0.57
Sole Sesame	4947.94	7259.20	1.47	2311.26	0.11	9.52	0.59
Blackgram + Sesame (additive series)	5242.82	8808.76	1.68	3565.94	0.12	8.31	0.52
Blackgram + Sesame 1:1 (replacement series)	5227.14	8236.40	1.58	3009.26	0.11	8.86	0.61
Blackgram + Sesame 3:1 (replacement series)	5227.14	9087.96	1.74	3860.82	0.12	8.03	0.65
Blackgram + Sesame 5:1 (replacement series)	5227.14	9785.96	1.87	4558.82	0.13	7.46	0.67
Blackgram + Sesame 1:3 (replacement series)	5227.14	7650.08	1.46	2422.94	0.10	9.54	0.59
Blackgram + Sesame 1:5 (replacement series)	5227.14	7091.68	1.36	1864.54	0.10	10.29	0.56
Blackgram + Sesame (seed mix)	5227.14	5974.88	1.14	747.74	0.08	12.21	0.44
SEm (±)	-	502.56	0.10	173.20	0.01	0.53	0.02
CD (*P= 0.05*)	-	1527.36	0.28	509.56	0.02	1.65	0.05

energy use efficiency and energy intensity (MJ $Rs.^{-1}$) were significantly higher with blackgram+sesame 5:1(replacement series) which was statistically at par with blackgram + sesame 3:1(replacement series) and blackgram + sesame additive series. The net energy return (MJ ha^{-1}) was significantly higher with blackgram + sesame 5:1 (replacement series) than all other treatments. The energy productivity (kg MJ^{-1}) was significantly higher with blackgram + sesame 5:1 (replacement series) which was statistically at par with blackgram + sesame 3:1 (replacement series), blackgram + sesame 1:1 (replacement series), blackgram + sesame additive series and sole sesame and blackgram.The higher blackgram equivalent yield under blackgram + sesame 5:1 (replacement series) and blackgram + sesame 3:1 (replacement series) resulted in higher energy output, energy use efficiency, energy productivity, net energy return and energy intensity. However, the specific energy (MJ kg^{-1}) was found significantly highest with blackgram + sesame (seed mix) than all other treatments.

CONCLUSION

Based on this experimentation it was evident that growth, development and yield of blackgram and sesame showed significant variation under given set of environment condition. Among various intercropping combinations tried, intercropping of blackgram with sesame in 5:1 replacement series as well as blackgram + sesame 3:1 replacement series proved be superior to all other intercropping systems by recording better growth and yield. These intercropping systems fetched higher economic returns, B: C ratio, LER, ATER, aggressivity, energy output, energy use efficiency, net energy return, energy productivity and energy intensity.

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