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Biological feasibility, economic viability and energy efficiency of intercropping fodder sorghum (*Sorghum bicolor*) in seed crop of *dhaincha* (*Sesbania aculeata*)

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ABSTRACT

A field experiment was conducted at CCSHAU, Hisar during *kharif* seasons of 2011 and 2012 with ten treatments in randomized block design replicated thrice to evaluate the intercropping of sorghum (*Sorghum bicolor*) in *dhaincha* (*Sesbania aculeata)* grown for seed. Results revealed that 1:3 row ratio of *sesbania* and sorghum at 22.5 cm spacing was found most economical and feasible intercropping system among all the treatments with highest *sesbania* equivalent yield (1.99 tonnes/ha), land equivalent ratio (1.52), system productivity index (1.69 tonnes/ha), monetary advantage index (13 119 ₹/ha), net return (7.20×10^3 ₹/ha), B:C ratio (1.24), Energy productivity (0.21 *sesbania* equivalent yield (kg/MJ) and system net energy return (625.4×10^3 MJ/ha) along with 14.8% and 41.3% reduction in *sesbania* seed yield and sorghum fodder yield, respectively, over sole cropping of both crops. Hence, for seed production *sesbania* was sown at 90 cm spacing intercropped with three rows of fodder sorghum in between two rows of *sesbania* to supplement the income of farmers.

Key words: Agrobiology, Energy return, Intercropping, Land equivalent ratio, Monetary advantage index, *Sesbania aculeata*, Sorghum

To attain the desired growth rate in agriculture for food security and sustainability of agriculture as well as to enhance the income of farmers, animal husbandry will play a vital role. Fodder shortage is one of the main limiting factor to enhance the production and productivity of cattles (ICAR 2012). Legumes like *dhaincha (Sesbania aculeata)* being quick growing, succulent, easily decomposable, withstands salinity or alkalinity and under poor drainage situations perform better as compared to other green manure crops. It is widely used as green manure crop to increase the crop productivity and sustain the soil fertility (Das and Sudhishri 2010). The availability of its seed for green manuring is a major constraint due to its low seed production and poor economics. *Dhaincha* being a long duration crop, provides opportunity for growing sorghum as intercrop fodder for better use of natural resources (Ghosh *et al.* 2007). But to get more seed yield of *dhaincha* and sorghum fodder yield simultaneously, there is need to explore feasibility and other related agro-economic aspects of intercropping of sorghum fodder in seed crop of dhaincha with different planting patterns with the dual objective to ensure the supply of *sesbania* seed and enhance the fodder production for huge cattle population.

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MATERIALS AND METHODS

A field experiment was carried out at agronomy research area of CCS Haryana Agricultural University, Hisar, Haryana, India (29º10'N latitude, 75º46'E longitude and 215.2 M altitude) during *kharif* seasons of 2011 and 2012 in randomized block design with ten treatments replicated thrice. The mean maximum, minimum temperature and total rainfall during crop season was 33.9ºC, 22.3ºC, 284.3 mm and 34.9ºC, 21.9ºC, 393.0 mm respectively in 2011 and 2012. The soil of the field was sandy loam in texture, slightly alkaline in pH (8.0), low in organic carbon (0.35%), poor in available nitrogen (147 kg/ha) and medium in available phosphorus (12 kg/ha) and rich in available potassium (147.5 kg/ha). The crop was raised with standard package of practices. DH 1 for *Sesbania aculeata* and HJ 513 for sorghum were used in the study. The crops were sown simultaneously on 11 July and 23 June during first and second year, respectively. Two irrigations were applied in first year while no irrigation was applied during second year because of sufficient rains. The sorghum was harvested on 17 and 23 September, respectively during first and second year of study, while *sesbania* was harvested on 21 and 17 November, respectively during first and second year of study. Recommended dose of fertilizers applied to *sesbania* and sorghum was (16 kg N+40 kg P_2O_5/ha) and

(75 kg N+40 kg P_2O_5/ha), respectively. Full amount of N and P in *sesbania* and only 21% of total N and full P in sorghum was applied at the time of sowing through DAP. The remaining 79% of N amount was top dressed in sorghum rows only through urea at 25 DAS. Sorghum and *sesbania* were sown manually with a seed rate of 50 kg/ha and 12.5 kg/ha, respectively after proper field preparation with 2 harrowings and 2 ploughings with cultivator attached with planker run by tractor after pre sown irrigation. After sowing one thinning and one hoeing at 20 DAS and second hoeing at 35 DAS were done manually. Harvesting and threshing of *sesbania* was done manually with 150 man hours and 114 man hours energy utilization. Two sprays of carbaryl 50WP @ 1 kg/ha at 25 DAS and 35 DAS were also done in sorghum for the control of stem borer.

To calculate the input energy, all inputs in the form of labour, seeds, fertilizers, hoeing, implements and pesticides used in crop production were taken into consideration with use of energy conversion factors as given in Table 1 (Devasenapathy *et al.* 2009). The farm produces were also converted into energy in terms of energy output (MJ). Energy equivalents for all inputs were summed to provide an estimate for total energy input. Output energy from product (grain) was calculated by multiplying the amount of productivity and its corresponding energy equivalent. Net energy return is the difference between the output energy produced and total input energy. Energy productivity (Kg *sesbania* equivalent yield (SBEY)/MJ) was calculated by dividing the *sesbania* equivalent yield of each intercropping system by their respective input energy requirement in MJ and energy intensiveness was expressed as energy out put of treatment in MJ/ kg P_2O_5/ha) per ₹ invested (Singh *et al.* 2013).

Different competition and yield advantage indices of intercropping were computed with formulae given as under.

Land equivalent ratio (LER), Willey (1979)

$$LER = \sum_{i}^{m} \frac{Y_i}{Y_{ij}}$$

where, Y_i, Individual crop yield under intercropping system; Y_{ij}, Individual crop yield under sole cropping system.

Table 1 Energy conversion factors used in study

Power source	Units	Equivalent energy (MJ)
Human labor		
Adult man	Man hour	1.96
Women	Women hour	1.57
Farm machinery	kg	62.7
Fertilizers		
N	kg	60.6
P_20_5	kg	11.1
Carbaryl (Insecticide)	kg	120
Crop produce		
Sesbania seeds	kg	14.7
Sesbania sticks	kg	12.5
Sorghum green fodder	kg	12.5
Diesel	liter	56.3

Relative crowding coefficient (RCC), De Wilt (1960)

Each component has its own coefficient (K) which gives a measure of whether component has produced more or less yield than expected. It can be calculated by the following formula:

$$RCC (K) = Kab \times Kba$$

$$K = \frac{Y_{ab} \times Z_{ba}}{(Y_{aa} - Y_{ab}) \times Z_{ab}} \times \frac{Y_{ba} \times Z_{ab}}{(Y_{bb} - Y_{ba}) \times Z_{ba}}$$

where, Y_{aa}, Yield of component ‘a’ as sole crop; Y_{bb}, Yield of component ‘b’ as sole crop; Y_{ab}, Yield of component ‘a’ as intercrop in combination with component ‘b’; Y_{ba}, Yield of component ‘b’ as intercrop in combination with component ‘a’; Z_{ab}, Sown proportion of component ‘a’ in combination with ‘b’; Z_{ba}, Sown proportion of component ‘b’ in combination with ‘a’.

Aggressivity (A), McGilchrist (1965)

Aggressivity gives simple measure of how much the relative yield increase in component ‘a’ is greater than that for component ‘b’.

$$A_{ab} = \frac{\text{Mixture yield of 'a'}}{\text{Expected yield of 'a'}} - \frac{\text{Mixture yield of 'b'}}{\text{Expected yield of 'b'}}$$

$$A_{ab} = \frac{Y_{ab}}{Y_{aa} \times Z_{ab}} - \frac{Y_{ba}}{Y_{bb} \times Z_{ba}}$$

where, Y_{aa}, Yield of component ‘a’ as sole crop; Y_{bb}, Yield of component ‘b’ as sole crop; Y_{ab}, Yield of component ‘a’ as intercrop grown in combination with component ‘b’; Y_{ba}, Yield of component ‘b’ as intercrop grown in combination with component ‘a’; Z_{ab}, Sown proportion of component ‘a’ in combination with ‘b’; Z_{ba}, Sown proportion of component ‘b’ in combination with ‘a’.

Crop equivalent yield (CEY), Verma and Modgal (1983)

Yield of different intercrops are converted into equivalent yield of any one crop based on price of the produce.

$$CEY = \sum_{i=1}^{m} (Y_i \times e_i)$$

where, Y_i, Yield of ith component; e_i, equivalent factor of ith component or price of ith crop.

Area time equivalent ratio (ATER), Hiebsch and Macollam (1980)

$$ATER = \frac{L_A \times T_A + L_B \times T_B}{T}$$

where, L_A and L_B are partial LER of component crops A and B, T_A and T_B are duration of crops A and B and T is the total duration of the intercropping system.

System productivity index (SPI), Odo (1991)

$$SPI = \left(\frac{SA}{LB} \times Lb\right) + Sa$$

where, SA and LB are the mean yields of the crop A and B as monoculture.

Sa and Lb are their yields in mixture.

Monetary advantage index (MAI), Pal *et al* (1985)

It is an index which tells the relative money value of produce under intercropping system.

$$\text{MAI} = \text{Value of combined yield of intercrop} \times \frac{\text{LER - 1}}{\text{LER}}$$

where, LER is land equivalent ratio.

The data presented in this research study are the pooled values of two years. The statistical methods described by Panse and Sukhatme (1995) were followed for statistical analysis and interpretation of the experimental results.

RESULTS AND DISCUSSION

INDICES ON THE BASIS OF BIOLOGICAL POTENTIAL

Seed yield and crop equivalent yield

The maximum seed and biological yield of *sesbania* and sorghum fodder yield was recorded under sole cropping as compared to intercropping (Table 2). The productivity level of both crops in sole cropping was significantly higher than all intercropping systems except 1:1 row ratio of *sesbania* and sorghum at 30 cm spacing. Among the intercropping systems maximum *sesbania* seed (1.05 tonnes/ ha) and biological yield (14.5 tonnes/ha) was obtained with 1:1 row ratio of *sesbania* and sorghum at 30 cm spacing (T_3) with a reduction of 2.8 and 2.0 percent, respectively over sole *sesbania* crop. By contrast, the minimum *sesbania* seed (0.79 tonne/ha) and biological yield (10.45 tonnes/ha) were obtained from 1:4 row ratio of *sesbania* and sorghum at 24 cm spacing (T_8) with a significant reduction of 26.8 percent over sole *sesbania* crop. The variation in productivity of *sesbania* in different intercropping treatments might be due to their variable competitive behaviour and number of rows per unit area. The increase in yield level of *sesbania* sole crop is ascribed to less competition, more availability and smooth partitioning of metabolites to all developing plant parts as compared to intercropped *sesbania*. These results corroborate the findings of Kujur *et al.* (2010), who reported significantly higher pigeonpea grain and biological yield than intercropping treatments.

The highest sorghum fodder yield (39.7 tonnes/ha) was obtained with sole crop sown at 25 cm spacing, which was significantly superior than all the intercropping treatments. Among intercropping treatments 1:3 row ratio of *sesbania* and sorghum at 22.5 cm spacing (T_6) was recorded with maximum sorghum fodder yield (26.7 tonnes/ ha) with a reduction of 32.7 percent over sole crop and it was significantly higher than all the intercropping treatments except T_8. These reduction in yield may be due to increased competition and population pressure in intercropping treatment reduced the average weight per plant due to increase in plant height, thin and slender plant stem (Sankaranarayanan *et al*. 2005). Among intercropping treatments significantly higher fodder yield of sorghum in T_6 and T_8 than other intercropping treatments could be ascribed to the more number of sorghum rows per unit area as compared to other intercropping systems.

All the intercropping treatments proved to be superior to monocultures of both *sesbania* and sorghum as evident by their equivalent yield (Table 2). The relative yield advantage on the basis of *sesbania* equivalent yield due to intercropping irrespective of row ratio pattern of intercropping ranged between 51.8 and 84.2% compared to *sesbania* equivalent yield of sole *sesbania* treatment. The *sesbania* equivalent yield was highest in T_6 treatment in which 1:3 rows of *sesbania* and sorghum were sown at 22.5 cm spacing. It was significantly higher than all other treatments tested weather as sole or intercrop. On the other

Table 2 Indices on the basis of biological potential under different intercropping systems (Pooled data of two years)

	Treatment	Yield (tonnes/ha)			*Sesbania* equivalent yield (tonnes/ha)
		Sesbania (Seed)	*Sesbania* (Biological)	Sorghum (Fodder)	
T_1	*Sesbania* sole at 60 cm spacing	1.08	14.80		1.08
T_2	Sorghum fodder sole at 25 cm spacing			39.69	1.59
T_3	1:1 row ratio of *sesbania* and sorghum at 30 cm spacing	1.05	14.54	17.80	1.77
T_4	1:2 row ratio of *sesbania* and sorghum at 20 cm spacing	0.91	13.15	22.28	1.80
T_5	1:2 row ratio of *sesbania* and sorghum at 30 cm spacing	1.02	11.54	21.42	1.87
T_6	1:3 row ratio of *sesbania* and sorghum at 22.5 cm spacing	0.92	11.32	26.68	1.99
T_7	1:3 row ratio of *sesbania* and sorghum at 30 cm spacing	0.88	10.45	23.33	1.81
T_8	1:4 row ratio of *sesbania* and sorghum at 24 cm spacing	0.79	10.73	26.27	1.85
T_9	2:3 row ratio of *sesbania* pair at 45 cm spacing and 3 rows of sorghum in 90 cm spacing between *sesbania* pairs	0.86	13.66	19.42	1.64
T_{10}	2:4 row ratio of *sesbania* pair at 60 cm spacing and 4 rows of sorghum in 120 cm spacing between *sesbania* pairs	0.84	13.32	20.24	1.65
SEm ±		0.02	0.34	0.73	0.03
CD (P = 0.05)		0.06	1.01	2.24	0.09

Table 3 Indices on the basis of biological potential under different intercropping systems (Pooled data of two years)

	Treatment	Relative crowding coefficient (RCC (K))			Aggresivity (A)		Land equivalent ratio (LER)		
		Sesbania	Sorghum	System	*Sesbania*	Sorghum	*Sesbania*	Sorghum	System
T_1	*Sesbania* sole at 60 cm spacing						1.00		1.00
T_2	Sorghum fodder sole at 25 cm Spacing							1.00	1.00
T_3	1:1 row ratio of *sesbania* and sorghum at 30 cm spacing	-2.43	0.95	–4.56	0.26	-0.26	0.98	0.45	1.43
T_4	1:2 row ratio of *Sesbania* and sorghum at 20 cm spacing	21.9	0.72	13.52	-0.08	0.08	0.84	0.57	1.40
T_5	1:2 row ratio of *sesbania* and sorghum at 30 cm spacing	3.85	0.67	1.67	-0.03	0.03	0.95	0.54	1.49
T_6	1:3 row ratio of *sesbania* and sorghum at 22.5 cm spacing	9.19	0.78	7.65	-0.28	0.28	0.84	0.67	1.52
T_7	1:3 row ratio of *sesbania* and sorghum at 30 cm spacing	12.61	0.73	8.29	-0.23	0.23	0.81	0.60	1.41
T_8	1:4 row ratio of *sesbania* and sorghum at 24 cm spacing	10.77	0.58	6.42	-0.38	0.38	0.73	0.67	1.40
T_9	2:3 row ratio of *sesbania* pair at 45 cm spacing and 3 rows of sorghum in 90 cm spacing between *sesbania* pairs	6.41	0.74	4.73	0.05	-0.05	0.80	0.49	1.29
T_{10}	2:4 row ratio of *sesbania* pair at 60 cm spacing and 4 rows of sorghum in 120 cm spacing between *sesbania* pairs	9.00	0.57	5.19	-0.07	0.07	0.77	0.51	1.28
	SEm ±	0.92	0.04	1.25	0.02	0.01	0.01	0.02	0.02
	CD (P = 0.05)	2.79	0.13	3.81	0.05	0.04	0.06	0.07	0.06

hand, the 2:3 row ratio of *sesbania* pair at 45 cm spacing and 3 rows of sorghum in 90 cm spacing between *sesbania* pairs (T_9) brought about the lowest equivalent yield. This may be accredited to balance competition, temporal complementarities and better utilization of resources by the component crops having differential rooting pattern, canopy distribution and nutritional requirements. Verma *et al.* (2005) also reported higher crop equivalent yield in intercropping system than sole crop. This might be owning to the efficient use of space, light and more efficient use of nutrients which produced positive effect on growth and yield of both the crops with additional yield of intercrop in the aforesaid intercropping treatments.

Relative crowding coefficient (RCC)

In all the intercropping treatments in this study except 1:1 row ratio of *sesbania* and sorghum at 30 cm spacing, *sesbania* appeared to highly dominant as it had higher value of RCC (K) than the sorghum intercrop in different intercropping system (Table 3). It may be inferred that *sesbania* utilized the resources more competitively than sorghum in intercropping systems. Khan *et al.* (2001), also reported that in cotton+sorghum intercropping, cotton has the maximum RCC (K) value than sorghum intercrop.

Among the intercropping treatments except 1:1 row ratio of *sesbania* and sorghum at 30 cm spacing in all the intercropping system the products of the individual RCC (K) value of the component crops was greater than one, so all the intercropping systems except this had yield advantages. Across the intercropping treatments, the maximum *sesbania* yield advantage RCC (K) was obtained from 1:2 row ratio of *sesbania* and sorghum at 20 cm spacing (T_4), while maximum sorghum yield advantage RCC (K) was obtained with 1:1 row ratio of *sesbania* and sorghum at 30 cm spacing (T_3). T_4 showed the highest yield advantage with system RCC (K) value of 13.52 which was significantly superior to all the intercropping system (Table 3). By contrast, the minimum yield advantage was recorded with T_3. These results are in line with the findings of Ahmad *et al.* (2006), who reported that maximum yield advantage (RCC (K) = 22.5) with sorghum+*sesbania* intercropping over other intercropping treatments. Similarly, Verma *et al.* (2005) also reported that narrow row spacing of pigeonpea with intercropping of sorghum showed the better performance than wider row spacing with highest RCC value of 15.1 due to higher plant population and better land utilization efficiency with component crops. Bhatti *et al.* (2006) also observed that among different intercropping systems of legumes + sesame, the maximum yield advantage was obtained from sesame + mungbean as indicated by its maximum K value.

Aggressivity (A)

The two year pooled data pertaining to aggressivity presented in Table 3 revealed that in all the intercropping treatments of *sesbania* and sorghum both the component crops did not compete equally. In all the intercropping systems except T_3 and T_9 the "A" value of *sesbania* base crop and sorghum intercrop were found negative and positive, respectively. It showed that with negative sign "A" value *sesbania* was dominated crop and sorghum was dominant crop in almost all the intercropping system. For *sesbania* highest and lowest "A" value were observed with 1:1 row ratio of *sesbania* and sorghum at 30 cm spacing (0.26) and 1:4 row ratio of *sesbania* and sorghum at 24 cm spacing (-0.38), respectively. This could be due to increased number of rows of sorghum in T_8 as compared to T_3, which increased the competition between plants and thereby resulting in the increase in dominance of sorghum over *sesbania* in T_8. Similarly highest (0.38) and lowest (-0.26) 'A' values for sorghum were found with T_8 and T_3, respectively. Ahmad *et al.* (2006) also reported that *sesbania* was dominant crop with A value of (-0.07) in intercropping system of sorghum + *sesbania* with dominant sorghum crop with A value (0.07). Dhima *et al.* (2007) also recorded almost similar finding in different intercropping systems of sorghum + cowpea and concluded that regardless of planting patterns the positive sign for sorghum and negative sign for cowpea indicate the dominance of sorghum over cowpea .

Land equivalent ratio (LER)

The data regarding LER of different intercropping systems presented in Table 3 indicated that LER values were greater than one in all the intercropping systems under different planning patterns. It indicates the yield advantage and biological efficiency of intercropping treatments over sole stand of either of component crops. The range of yield advantage was varied from 28 to 52 percent. Among intercropping systems the significantly highest LER (1.52) was found with 1:3 row ratio of *sesbania* and sorghum at 22.5 cm spacing (T_6) except T_5 with LER (1.49). In contrast, the minimum LER (1.28) was recorded with T_{10}. The yield advantage owing to intercropping might be attributed to balanced competition and better utilization of available resources than sole cropping resulting in higher productivity per unit area. Verma *et al.* (2005) also recorded the highest LER (1.58) with sorghum fodder + pigeonpea at 75 cm spacing compared to sole cropping of each crop. Ahmad *et al.* (2006) also found that LER of sorghum + *Sesbania* intercropping system was 1.64 and concluded that all intercropping systems gave higher LER than their respective sole crops. The results are also in agreement with findings

Table 4 Indices on the basis of land use efficiency and economic viability under various intercropping systems (Pooled data of two years)

	Treatment	Area time equivalent ratio (ATER)	System productivity index (SPI) (t/ha)	Monetary advantage index (MAI) (₹/ha)	Total cost (× 10³ ₹/ha)	Net return (× 10³ ₹/ha)	B:C ratio
T_1	*Sesbania* sole at 60 cm spacing				20.95	2.58	1.13
T_2	Sorghum fodder sole at 25 cm Spacing				24.70	3.90	1.16
T_3	1:1 row ratio of *sesbania* and sorghum at 30 cm spacing	1.20	1.60	10620	29.88	5.87	1.20
T_4	1:2 row ratio of *Sesbania* and sorghum at 20 cm spacing	1.11	1.54	10294	32.60	3.36	1.10
T_5	1:2 row ratio of *sesbania* and sorghum at 30 cm spacing	1.21	1.64	12056	29.66	7.19	1.23
T_6	1:3 row ratio of *sesbania* and sorghum at 22.5 cm spacing	1.18	1.69	13119	31.64	7.20	1.24
T_7	1:3 row ratio of *sesbania* and sorghum at 30 cm spacing	1.10	1.51	10187	29.55	5.79	1.20
T_8	1:4 row ratio of *sesbania* and sorghum at 24 cm spacing	1.06	1.57	10291	31.04	5.07	1.17
T_9	2:3 row ratio of *sesbania* pair at 45 cm spacing and 3rows of sorghum in 90 cm spacing between *sesbania* pairs	1.04	1.43	7403	30.56	2.65	1.09
T_{10}	2:4 row ratio of *sesbania* pair at 60 cm spacing and 4rows of sorghum in 120 cm spacing between *sesbania* pairs	1.02	1.42	7390	29.66	3.62	1.12
SEm ±		0.02	0.05	468			
CD (P = 0.05)		0.06	0.15	1434			

Cost of inputs and farming operations was followed same for both the year of study according to the data provided by the deptt. of economics, CCSHAU, Hisar for *kharif* 2012-13.

of Sheoran *et al.* (2009), who concluded that all the intercropping combinations irrespective of row arrangement resulted in LER greater than one indicating yield advantage due to intercropping with highest LER of 1.39 with maize + greengram in 1:1 row proportion.

INDICES ON THE BASIS OF LAND USE EFFICIENCY AND ECONOMIC VIABILITY

Area time equivalent ratio (ATER)

In all treatments, ATER values were smaller than LER values (Table 4), which indicate that there is over estimation of resource utilization in the LER. Thus contrary to LER, ATER is free from problems of over estimation of resource utilization. All the intercropping system recorded ATER value more than one indicating better land utilization efficiency than their sole crops (Table 4). Among intercropping systems, ATER values indicated an yield advantage in range of 2 to 21% in intercropping compared with sole cropping of *sesbania*. Among intercropping treatment highest ATER values of 1.21 was found with 1:2 row ratio of *sesbania* and sorghum at 30 cm spacing (T_5) closely followed by 1:1 row ratio of *sesbania* and sorghum at 30 cm spacing (T_3), which were statistically at par with T_6 (1.18). Higher values of ATER in intercropped treatment compared with sole crop were attributed to efficient utilization of natural (land and light) and added (fertilizer and water) resources. Verma *et al.* (2005) also reported a ATER value of 1.21 for 1:2 row ratio of pigeonpea at 75 cm spacing and sorghum fodder which was highest among intercropping treatments.

System Productivity Index (SPI)

System productivity index was found highest (1.69 tonnes/ha) with 1:3 row ratio of *sesbania* and sorghum at 22.5 cm spacing (T_6) which was statistically at par with T_3, T_5 and T_8 (Table 4). This highest level of productivity in aforesaid treatments could be attributed to their significantly higher ATER and LER values which indicated the more yield advantage, biological efficiency and better land utilization in these intercropping treatments. Paired row pattern of *sesbania* either at 90 cm or 120 cm spacing with 3 or 4 rows of sorghum, i e T_9 and T_{10} were most inefficient intercropping system with lowest value of SPI. This explains that *sesbania* sown in paired row pattern causes competition between itself for various resources as well as suppress the intercrop more severely. Kumar and Thakur (2009) also observed similar results in maize based intercropping systems with 34.5% higher system productivity in maize + soybean-*gobhi sarson* compared to pure maize crop.

Monetary Advantage Index (MAI)

Monetary advantage index followed the same trend as that of system productivity index and relative value total (Table 4). The highest MAI (13 119 ₹/ha) was found with 1:3 row ratio of *sesbania* and sorghum at 22.5 cm spacing (T_6) closely followed by 1:2 row ratio of *sesbania* and sorghum at 30 cm spacing (T_5). In contrast, lowest MAI values (7 390 ₹/ha) was found with T_{10}. The reason could be increased number of intercrop rows in between *sesbania* pairs which cause sharp decline in sorghum yield and thus less SPI, ATER and MAI values were obtained. These results corroborate the findings of Kumar and Thakur (2009), who found the highest MAI (4.78×10^3 ₹/ha) with intercropping of greengram + maize in 1:1 row ratio.

Economics

Among all the intercropping systems 1:2 row ratio of *sesbania* and sorghum at 20 cm spacing (T_4) required highest total cost of production (32.60×10^3 ₹/ha), which was 42.9 percent more than average cost of cultivation for sole crop of either of component crops (Table 4). It was closely followed by T_6 and T_8. Higher cost of cultivation of aforesaid intercropping treatments was due to increased number of rows per unit area as indicated from their minimum row spacing. Intercropping of *sesbania* with sorghum fodder irrespective of row pattern gave the higher net return per hectare than sole crop of *sesbania*. Among intercropping systems 1:3 row ratio of *sesbania* and sorghum at 22.5 cm (T_6) gave the maximum net return (7.20×10^3 ₹/ha), which was 179.0% and 84.6% higher than net return obtained with sole crop of *sesbania* and sorghum, respectively. It was closely followed by T_5. This higher net return in these intercropping systems was mainly owing to their respective *sesbania* and sorghum equivalent yield. These results are in conformity with the results of Kujur *et al.* (2010) and Ramamoorthy *et al.* (2004). Same trend was also observed with benefit: cost ratio and net returns per rupee invested. The highest B:C ratio (1.24) was found with 1:3 row ratio of *sesbania* and sorghum at 22.5 cm spacing (T_6) closely followed by T_5 or T_3. Verma *et al.* (2005) also reported higher B:C ratio of 4.96 in 1:2 row ratio of pigeonpea and sorghum in 75 cm spacing as compared to wider spacing of 100 cm in intercropping and sole crop of component crops.

INDICES ON THE BASIS OF ENERGY USE EFFICIENCY

Energy budget

The energy budget revealed that the maximum system input energy was recorded under sole crop of sorghum (11.32×10^3 MJ/ha), which was 127.3% more than lowest system input energy (4.98×10^3MJ/ha) with sole crop of *sesbania* (Table 5). Among the intercropping systems highest input energy was found with 1: 4 row ratio of *sesbania* and sorghum at 24 cm spacing which was 101.8% higher than sole *sesbania* crop. In intercropping system increase in input energy was due to increased number of sorghum rows as intercrop which required more input in the form of seeds, fertilizer, pesticides and human labours.

The maximum system output energy was found with sole crop of sorghum (714.88×10^3 MJ/ha), while minimum was noted with sole crop of *sesbania* (201.01×10^3 MJ/ha) (Table 5). This was mainly due to higher amount of biomass production in sole sorghum (39.7 tonnes/ha) as compared to *sesbania* sole crop. Among the intercropping systems

Table 5 Indices on the basis of energy use efficiency under various intercropping systems (Pooled data of two years)

	Treatment	System input energy ($\times 10^3$ MJ/ha)	System output energy ($\times 10^3$ MJ/ha)	System net energy return ($\times 10^3$ MJ/ha)	Energy productivity (kg SBEY/MJ)	Energy intensiveness (MJ/‘)
T_1	*Sesbania* sole at 60 cm spacing	4.98	201.01	196.10	0.21	9.59
T_2	Sorghum fodder sole at 25 cm Spacing	11.32	714.88	703.56	0.14	28.94
T_3	1:1 row ratio of *sesbania* and sorghum at 30 cm spacing	8.15	518.24	510.10	0.21	17.34
T_4	1:2 row ratio of *Sesbania* and sorghum at 20 cm spacing	9.11	579.85	570.74	0.19	17.79
T_5	1:2 row ratio of *sesbania* and sorghum at 30 cm spacing	9.11	544.01	534.89	0.20	18.34
T_6	1:3 row ratio of *sesbania* and sorghum at 22.5 cm spacing	9.73	635.13	625.40	0.21	20.10
T_7	1:3 row ratio of *sesbania* and sorghum at 30 cm spacing	9.73	562.71	552.98	0.18	19.04
T_8	1:4 row ratio of *sesbania* and sorghum at 24 cm spacing	10.05	619.78	609.73	0.17	19.97
T_9	2:3 row ratio of *sesbania* pair at 45 cm spacing and 3rows of sorghum in 90 cm spacing between *sesbania* pairs	8.72	532.38	523.60	0.18	17.42
T_{10}	2:4 row ratio of *sesbania* pair at 60 cm spacing and 4rows of sorghum in 120 cm spacing between *sesbania* pairs	9.11	542.55	533.43	0.18	18.29

SBEY, *Sesbania* equivalent yield. Cost of inputs and farming operations was followed same for both the year of study according to the data provided by the department of economics, CCSHAU, Hisar for *kharif* 2012-13.

highest output energy (635.13×10^3 MJ/ha) was found with T_6 which was 215.9% more and 11.1% less than output energy of sole crop of *sesbania* and sorghum, respectively. This can be ascribed to its better seed and sorghum fodder yield compared to other intercropping. It was also indicated by its highest *sesbania* and sorghum equivalent yield values (Table 2). Similar results were also reported by Tuti *et al.* (2013), who reported highest output energy (213.7×10^3 MJ/ha) with pigeonpea – wheat system. The lowest values were recorded with 1:1 row ratio of *sesbania* and sorghum at 30 cm spacing due to lowest sorghum fodder yield among all the intercropping treatment. The maximum system net energy return (625.40×10^3 MJ/ha) and energy ratio (65.2) were obtained with 1: 3 row ratio of *sesbania* and sorghum at 22.5 cm spacing (T_6) because of higher system productivity. The lowest system net energy return (196.10×10^3 MJ/ha) was found with *sesbania* sole crop mainly because of too low system productivity. Singh *et al.* (2008) also reported more net energy returns due to less input energy and more output energy in different cropping systems.

Energy productivity (kg *sesbania* equivalent yield per MJ input energy) was found maximum (0.21) with T_1, T_3 and T_6, while sorghum sole was observed with lowest energy productivity values (0.14). This supports the observation of Devasenapathy *et al.* (2009), who also calculated the energy productivity of different crops. This might be on account of highest *sesbania* equivalent yield of this particular intercropping treatment. Sole sorghum fodder crop gave the highest energy intensiveness value (28.94 MJ/ha) and it was 201% higher than *sesbania* sole crop (9.59 MJ/ha). It could be attributed to variation in yield level of both the component crops (39.7 tonnes/ha) for sorghum fodder yield to 1.08 tonnes/ha seed yield of *sesbania*.

Among intercropping treatments 1:3 row ratio of sesbania and sorghum at 22.5 cm (T6) spacing was observed with highest energy intensiveness (20.10 MJ/ha), which was 109.3% more than *sesbania* sole crop and 30.4% less than sorghum sole crop closely followed by 1:4 row ratio of *sesbania* and sorghum at 24 cm spacing (T_8). It might be due to their respective total cost of production and level of output energy depicted by their system productivity.

Based on two years study it can be concluded that the intercropping system of 1:3 row ratio of *sesbania* and sorghum at 22.5 cm spacing was found most economical and feasible with highest *sesbania* equivalent yield (1.99 tonnes/ha), land equivalent ratio (1.52), system productivity index (1.69 tonnes/ha), monetary advantage index (13119 ₹/ha), net return (7.20×10^3 ₹/ha), B:C ratio (1.24) and energy productivity (0.21 kg SBEY/MJ) closely followed by 1:2 row ratio of *sesbania* and sorghum at 30 cm spacing.

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