Indian Journal of Agricultural Sciences **87** (2): 225–33, February 2017/Article
https://doi.org/10.56093/ijas.v87i2.67635

Production potential, energy efficiency and economics of wheat (*Triticum aestivum*) succeeding fodder sorghum intercropped in seed crop of *dhaincha* (*Sesbania aculeata*)

A K DHAKA[1], SATISH KUMAR[2], R K PANNU [3], KARMAL MALIK[4], BHAGAT SINGH [5] and RAMPRAKASH[6]

CCS Haryana Agricultural University, Hisar, Haryana 125 004

Received: 16 December 2014; Accepted: 26 October 2016

ABSTRACT

A field experiment was conducted at CCSHAU, Hisar during 2011-12 and 2012-13 to evaluate the intercropping of sorghum (*Sorghum bicolor*) in *dhaincha* (*Sesbania aculeata)* grown for seed during *kharif* season and their impact on succeeding wheat grown with three levels of nitrogen [50, 75 and 100 % recommended dose of nitrogen (RDN)] in split plot design with three replications. The results revealed that 1:1 row ratio of *dhaincha* and sorghum at 30 cm spacing succeeded by wheat was found most economical and feasible cropping system among all the treatments with highest wheat equivalent yield (7.22 tonnes/ha), system profitability (₹ 241/ha/day), production efficiency (2.44 tonnes WEY/ha/day), net return (71.4 × 10^3 ₹/ha), B:C ratio (1.32), energy productivity (285.4 kg/ MJ) and apparent nutrient use productivity of 20.3 kg WEY/ha-kg. The 1:1 row ratio of *dhaincha* with sorghum yielded almost equal seed yield of *dhaincha* (only 2.8% reduction) with additional yield of 17.8 tonnes/ha sorghum fodder over sole crop. Hence, for seed production *dhaincha* be sown at 60 cm spacing intercropped with one row of fodder sorghum in between two rows of *dhaincha* followed by wheat to supplement the income of farmers.

Key words: B:C ratio, Crop equivalent yield, Energy productivity, Intercropping, Net returns, *Sesbania aculeata,* Sorghum, Wheat

Current agriculture is confronted with formidable problems of stagnating production due to decline in factor productivity, degrading soil health, inefficiency of current production practices, scarcity of resources, and high cost of cultivation and low returns to the farmers as ill effects of green revolution which concentrates on maximum output but overlooks input efficiency. On the other hand per capita land availability is going to decrease, thus this limitation imposing more pressure to produce more food, feed, fibre, fuel and fodder per unit area to meet basic needs. The problem is likely to be further execrated by the climate change which poses new threats for sustainability of major cropping systems.

To meet out the challenges imposed by overuse of natural resources and climate change and to sustain productivity level with optimum use of agricultural inputs, some cropping system, resource conservation, socio-economic and policy based mitigation and adaptation measures like changing the cropping calendar and improved crop management through inclusion of legume and green manuring crops in crop rotations and intercropping of legumes with cereals have many potential benefits such as stable yields, better use of resources, weeds, pest and diseases reduction, increased protein content of cereals, reduced nitrogen leaching as compared to sole cropping systems. (Venkateswarlu *et al.* 2009). In general, grain yield of succeeding crop increased markedly when legumes preceded them compared with that when cereals preceded (Tanwar *et al.* 2014). Legumes like *Sesbania aculeata* (*Dhaincha*) is widely used as green manure crop to increase the crop productivity and to sustain the soil fertility as the premier green manure amongst all the green manure crops. A lot of research work on *dhaincha* as green manure crop has been done, but very few research findings related to the seed production, agronomy and intercropping under this crop were found in literature. The constraints which stand in the way of popularization of *Sesbania aculeata* as green manure crop is inadequate availability of quality seeds at reduced cost due to its low seed production and poor economics. At present, the India is facing a net deficit of 62.8% green fodder supply with current supply of 395 million tonnes against demand of 1 061 million tonnes (ICAR 2012).

[1]Assistant Professor (email: dhakaanilkumar@yahoo.in), Department of Agronomy, [2] Professor and Associate Dean, PGS, [3]Dean, College of Agriculture, [4]Assistant Scientists, Department of Agronomy, [5]Wheat Agronomist, [6]Assistant Scientist, Department of Soil Science.

Among the *kharif* forage crops, sorghum (*Sorghum bicolor* L.) possesses a wide adaptability because of its xerophytic characteristics. Keeping in view the above facts, the present study was designed to evaluate the performance of wheat (*Triticum aestivum* L.) succeeding fodder sorghum intercropped in seed crop of *dhaincha* to motivate farmers for seed production of *dhaincha* along with an additional yield of sorghum fodder as inter-crop in *kharif* season and to get enhanced total productivity of system by taking wheat in following *rabi* season.

MATERIALS AND METHODS

A field experiment was carried out at CCS Haryana Agricultural University, Hisar (29°10'N latitude, 75°46'E longitude and 215.2 M altitude), Haryana, India during 2011-12 and 2012-13 with 10 treatments to evaluate the intercropping of sorghum in *dhaincha* grown for seed during *kharif* season in randomized block design with three replications and all these treatments were succeeded by wheat grown with three levels of nitrogen, ie 50, 75 and 100% recommended dose of nitrogen (RDN) in split plot design replicated thrice during *rabi* season. The mean maximum, minimum temperature and total rainfall during *kharif* season was 33.1°C, 20.3°C , 284.3 mm and 33.1°C, 20.5°C, 398.4 mm, respectively, in 2011 and 2012. While in *Rabi* season the mean maximum, minimum temperature and total rainfall was 26.4°C, 10.7°C, 47.2 mm and 26.0°C, 11.3°C , 114.6 mm, respectively, in 2011-12 and 2012-13. The soil of the field was sandy loam in texture, slightly alkaline in pH (8.0), low in organic carbon (0.39%), poor in available nitrogen (194 kg/ha) and medium in available phosphorus (22.0 kg/ha) and rich in available potassium (258 kg/ha). The seed rate of 15, 50 and 125 kg/ha was used for the crop of *dhaincha*, sorghum and wheat, respectively. *Dhaincha* variety DH-1, HJ-513 of sorghum and WH 711 of wheat were used in the study. The crops were sown on 11 July and 23 June during *kharif* season of first and second year, respectively. Wheat was sown on 24th November and 27th November, respectively, during first and second year of study. The sorghum and *dhaincha* were harvested on 17th and 23rd September and 21st and 17th November during first and second year, respectively. Wheat was harvested on 25th and 28th April during first and second year, respectively. Recommended dose of fertilizers were applied to *dhaincha*, sorghum and wheat (16 kg N + 40 kg P_20_5 / ha), (75 kg N + 40 kg P_20_5 / ha) and (150 kg N + 60 kg P_20_5 + 60 kg K_2O + 25 kg $ZnSO_4$ /ha), respectively. Full amount of N and P in *dhaincha* 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. In wheat half nitrogen along with full phosphorus, potassium and zinc were applied as basal dose, remaining half dose of nitrogen was applied after first irrigation according to the treatment. Sorghum and *dhaincha* were sown manually after proper field preparation with 2 harrowing and 2 ploughing with cultivator following by planking. Wheat was sown with seed drill after field preparation with three harrowing followed by planking. After sowing one thinning and one hoeing at 20 DAS and second hoeing at 35 DAS were done manually in *kharif* crop, while in wheat clodinafop (Topic) @ 400 g/ha and metsulfuron (Algrip) @ 20g/ha were applied at 30 DAS for control of grassy and broad- leaved weeds, respectively. Two irrigations in *kharif* and four irrigations were applied in *rabi* season, respectively, during both the years.

The composite soil samples were collected before sowing and after the harvest of crops. The available N, P, K in kg/ha and organic carbon (%) were estimated as per the method suggested by Chopra and Kanwar (1991). The apparent nutrient use productivity was calculated by dividing the wheat equivalent yield of the system with the total quantity of nutrients (NPK) used in different crops in the system. To record the yield attributing characters of crops five plants per plot were tagged and the seed as well as biological yield harvested per plot was converted in kg/ha. The economics of different treatments was calculated by using the MSP recommended by the ministry of agriculture, India.

The energy equivalents of all inputs in the form of labour, seeds, fertilizers, hoeing, implements and pesticides and the energy output as produce was converted into energy (MJ) as per conversion factors as given by Devasenapathy *et al.* 2009. Net energy return is the difference between the output energy produced and total input energy. Energy ratio was determined as energy output divided by input energy. Energy Productivity (kg wheat equivalent yield (WEY)/MJ) was calculated by dividing the wheat equivalent yield of each intercropping system by their respective input energy requirement in MJ and energy intensiveness was expressed as energy output of treatment in MJ/ per ₹ invested (Singh *et al.* 2013).

The response of different treatments were similar during both the years, hence, the data was pooled and analyzed according to statistical methods described by Panse and Sukhatme (1995) for interpretation of the results. Land equivalent ratio (LER) and crop equivalent yield were computed with formulae given by Pal *et al* (1985) are as under.

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

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

Yield of different intercrops were converted into crop equivalent yield (CEY) of any one crop based on price of the produce. The price of sorghum fodder, *dhaincha* grain and wheat grain were ₹ 0.72 , ₹ 18.00 and ₹ 12.8/kg.

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

where, Y_i = yield of ith component, e_i = equivalent factor of ith component or price of ith crop.

RESULTS AND DISCUSSION

Kharif season

Dhaincha yield and yield attributes

The highest *dhaincha* seed yield (1.08 tonnes/ha) was recorded in sole crop of *dhaincha* sown at 60 cm spacing and it was significantly higher than all other treatments except 1:1 and 1:2 row ratio of *dhaincha* and sorghum at 30 cm spacing (Table 1). Among intercropping treatments the maximum *dhaincha* seed yield was observed with 1:1 row ratio of *dhaincha* and sorghum with a reduction of 2.8% over sole crop. It was significantly higher than all intercropping treatments except 1:2 row ratio of *dhaincha* and sorghum at 30 cm spacing. The possible reason for higher yield in this treatment was less competition between sorghum and *dhaincha* as in other intercropping treatments the row ratio of sorghum was higher along with reduced row numbers of *dhaincha*. Similar trend was also observed with *dhaincha* biological yield. The highest *dhaincha* biological yield of 14.8 tonnes/ha was found with sole crop and it was significantly higher than all treatments except 1:1 row ratio of *dhaincha* and sorghum at 30 cm spacing. Among intercropping treatments 1:1 row ratio yielded highest *dhaincha* biological yield with 1.75% reduction over sole crop. It was significantly higher than all other intercropping treatments except 2:3 row ratio of *dhaincha* pairs at 45 cm spacing and 3 rows of sorghum in 90 cm spacing between *dhaincha* pairs. The higher biological yield in this treatment was due to higher number of *dhaincha* rows and wider spacing with less competition between *dhaincha* and sorghum. These results corroborate the findings of Verma *et al.* (2005) and Kujur *et al.* (2010).

Row ratio of 1:1 and 1:2 in *dhaincha* and sorghum at 30 cm spacing were found with significantly higher number of branches per plant as compared to all other inter cropping treatment except 1:3 row ratio and *dhaincha* and sorghum at 30 cm spacing with a reduction of 7.1 and 11.2%, respectively, over sole crop of *dhaincha* (Table 1). While the lowest number of branches were observed with 1:2 row ratio of *dhaincha* and sorghum at 20 cm spacing with reduction of 26.5% over sole crop. The possible reason for this reduction of branches per plant may be the severe competition between *dhaincha* and sorghum with high population and narrow spacing in vegetative phase which leads to decrease in the total length of plant having pods.

Pod length (26.0 cm), highest number of pods per plant (188) and seeds per pod (38.2) were found with sole crop of *dhaincha*. While, among intercropping treatments 1:1 row ratio of dhaincha and sorghum at 30 cm spacing with significantly higher number of pods per plant (178), seeds per pod (37.8) and maximum pod length of 25.7 cm with a reduction of 5.3, 1.0 and 1.1%, respectively, over sole crop of *dhaincha.* This treatment was closely followed by 1:2 row ratio of *dhaincha* and sorghum at 30 cm spacing. The lowest values of all these yield attributes were observed with 1:2 row ratio of *dhaincha* and sorghum at 20 cm spacing due to maximum number of rows with lowest spacing and highest competition between *dhaincha* and sorghum for inputs. Among various yield attributes computed for different intercropping systems, number of branches per plant (r = 0.78), pod length (r = 0.77), number of pods per plant (r = 0.80) and number of seeds per pod (r =0.76) were found highly associated with *dhaincha* seed yield.

Sorghum yield and yield attributes

The highest fodder yield of sorghum (39.7 tonnes/ha) was recorded in sole crop sown at 25 cm spacing. Among the intercropping treatments 1:3 row ratio of *dhaincha* and sorghum sown at 22.5 cm spacing produced the highest green fodder yield (26.7 t/ha) and dry weight per plant (8.7g) with a reduction of 32.7 and 17.9%, respectively, and it was statistically at par with 1:4 and 1:2 row ratio of *dhaincha* and sorghum at 24 cm and 20 cm spacing, respectively (Table 1). The lowest sorghum green fodder yield and dry weight by plant was found with 1:1 row ratio of *dhaincha* and sorghum at 30 cm spacing with a reduction of 55.2 sand 44.3%, respectively, over sole crop. This might be due to the increased number of sorghum rows; and reduction in yield may be due to the increased competition and population pressure in intercropping treatment that reduced the average weight per plant due to increase in plant height, thinness and slenderness of plant stem (Sankaranarayanan *et al.* 2005). Tanwar *et al.* (2014) also found 34.5 % reduction in stover yield of sorghum in sorghum+ cowpea intercropping system over sole sorghum planting. The same trend was also observed with dry fodder yield with a average reduction of 75.4% in weight as compared to green fodder.

The maximum plant height of sorghum (273.0 cm) was observed with 1:2 row ratio of *dhaincha* and sorghum at 20 cm spacing, which was 9.3% more than sole crop of sorghum and it was statistically at par with 1:3 and 1:4 row ratio of *dhaincha* and sorghum at 22.5 and 24 cm spacing, respectively. The increase in plant height could be attributed to severe competition between the component crops with narrow spacing.

Dhaincha equivalent yield

The *dhaincha* equivalent yield was significantly highest (1.99 t/ha) with 1:3 row ratio of *dhaincha* and sorghum at 22.5 cm spacing (Table 1). On the other hand, the 2:3 row ratio of *dhaincha* pair at 45 cm spacing and 3 rows of sorghum in 90 cm spacing between *dhaincha* pairs brought about the lowest *dhaincha* equivalent yield. In the present finding highest *dhaincha* equivalent yield in 1:3 row ratio of *dhaincha* and sorghum at 22.5 cm spacing was due to highest sorghum fodder yield and second highest *dhaincha* seed yield in this intercropping system. Verma *et al.* (2005) also reported higher crop equivalent yield in intercropping system than sole crop. 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.

Table 1 Effect of different intercropping systems on *dhaincha* and sorghum yield, *Dhaincha* equivalent yield and LER economic (Pooled data of two years)

Treatment	*Dhaincha*						Sorghum				*Dhaincha* equivalent yield (t/ha)	Land equivalent ratio (LER)
	Dhaincha seed yield (t/ha)	*Dhaincha* biological yield (t/ha)	Number of branches / plant	Pod length (cm)	Number of pods per plant	Number of seeds per pod	Sorghum green fodder yield (t/ha)	Dry weight/ plant (g)	Plant height at harvest(cm)	No. of leaves/ plant		
Dhaincha sole at 60 cm spacing	1.08	14.8	26.8	26.0	188	38.2				-	1.08	1.00
Sorghum fodder sole at 25 cm Spacing							39.7	10.61	249.7	13.7	1.59	1.00
1:1 row ratio of *dhaincha* and sorghum at 30 cm spacing	1.05	14.54	24.9	25.7	178	37.8	17.8	5.95	246.3	12.1	1.77	1.43
1:2 row ratio of *dhaincha* and sorghum at 20 cm spacing	0.91	13.15	19.7	21.9	158	34.5	25.3	7.02	273.0	12.5	1.80	1.40
1:2 row ratio of *dhaincha* and sorghum at 30 cm spacing	1.02	11.54	23.8	24.5	176	36.8	21.4	6.94	245.8	13.4	1.87	1.49
1:3 row ratio of *dhaincha* and sorghum at 22.5 cm spacing	0.92	11.32	20.7	22.5	163	35.2	26.7	8.72	269.0	12.6	1.99	1.52
1:3 row ratio of *dhaincha* and sorghum at 30 cm spacing	0.88	10.45	23.3	24.2	171	36.7	23.3	7.82	245.4	13.3	1.81	1.41
1:4 row ratio of *dhaincha* and sorghum at 24 cm spacing	0.79	10.73	21.3	22.8	164	35.4	26.3	8.50	264.7	12.9	1.85	1.40
2:3 row ratio of *dhaincha* pair at 45 cm spacing and 3rows of sorghum in 90 cm spacing between *dhaincha* pairs	0.86	13.66	20.8	23.0	164	35.6	19.4	6.32	256.5	13.0	1.64	1.29
2:4 row ratio of *dhaincha* pair at 60 cm spacing and 4rows of sorghum in 120 cm spacing between *dhaincha* pairs	0.84	13.32	21.8	23.4	166	35.8	20.2	6.54	247.5	12.8	1.65	1.28
SEm ±	0.03	0.35	0.59	0.60	3.53	0.62	0.61	0.22	6.46	0.35	0.06	0.05
CD (P=0.05)	0.09	1.06	1.80	1.82	10.67	1.89	1.84	0.69	19.56	NS	0.20	0.17

Table 2 Effect of preceding intercropping systems and nitrogen levels on yield and yield attributes of wheat (Pooled data of two years)

Treatment	Wheat seed yield (t/ha)	Wheat biological yield (t/ha)	Harvest Index (%)	Total no. of tillers/mrl	No. of effective tillers/mrl	Spike length (cm)	Spikelets/ spike	Grains/spike	Test weight (g)
Nitrogen levels									
N_1-50% RDN	4.20	11.4	36.8	108.6	95.2	9.5	19.9	39.3	42.5
N_2-75% RDN	4.39	11.99	36.6	114.0	97.4	9.9	20.6	41.4	43.2
N_3-100% RDN	4.55	12.39	36.7	121.4	103.0	10.3	21.8	43.5	44.5
SEm ±				0.6	0.5	0.1	0.3	0.4	0.1
CD (P=0.05)	0.089	0.284	NS	1.9	1.5	0.4	0.9	1.2	0.5
Intercropping treatments									
Dhaincha sole at 60 cm spacing fb wheat	4.93	12.83	38.5	121.4	103.5	11.2	21.9	42.2	44.3
Sorghum fodder sole at 25 cm spacing fb wheat	3.79	11.17	33.9	97.2	89.4	9.4	20.2	39.9	42.7
1:1 row ratio of *dhaincha* and sorghum at 30 cm spacing fb wheat	4.73	12.56	37.7	120.4	100.8	10.8	21.8	42.1	43.9
1:2 row ratio of *dhaincha* and sorghum at 20 cm spacing fb wheat	4.35	11.68	37.1	110.4	94.5	10.4	21.2	41.5	43.6
1:2 row ratio of *dhaincha* and sorghum at 30 cm spacing fb wheat	4.50	12.2	36.5	116.4	99.7	10.4	21.6	41.8	43.5
1:3 row ratio of *dhaincha* and sorghum at 22.5 cm spacing fb wheat	4.16	11.49	36.2	105.3	92.2	9.8	21.0	40.8	43.0
1:3 row ratio of *dhaincha* and sorghum at 30 cm spacing fb wheat	4.27	11.55	36.9	107.2	93.3	10.1	21.5	41.3	43.6
1:4 row ratio of *dhaincha* and sorghum at 24 cm spacing fb wheat	4.05	11.36	35.7	102.6	90.7	9.8	20.7	40.5	42.9
2:3 row ratio of dhaincha pair at 45 cm spacing and 3rows of sorghum in 90 cm spacing between *dhaincha* pairs fb wheat	4.57	12.33	37.3	118.9	100.2	10.6	21.8	41.9	43.7
2:4 row ratio of dhaincha pair at 60 cm spacing and 4rows of sorghum in 120 cm spacing between *dhaincha* pairs fb wheat	4.47	12.1	37.1	113.8	98.3	10.3	21.5	41.7	43.6
SEm ±	0.05	0.09	0.60	1.0	0.5	0.1	0.2	0.3	0.1
CD (P=0.05)	0.177	0.26	1.82	2.9	1.5	0.4	0.7	0.8	0.3

Land equivalent ratio (LER)

The LER values were greater than one in all the intercropping systems under different planting patterns. It indicated the yield advantage and higher biological efficiency of intercropping treatments over sole stand of either of components crops. The range of yield advantage was varied from 28 to 52%. The significantly highest LER (1.52) was found with 1:3 row ratio of *dhaincha* and sorghum at 22.5 cm spacing and it was closely followed by 1:2 row ratio of *dhaincha* and sorghum at 30 cm spacing with LER (1.49). In contrast, the minimum LER (1.28) was recorded with 2:4 row ratio of *dhaincha* pair at 60 cm spacing and 4 rows of sorghum in 120 cm spacing between *dhaincha* pairs. 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. Ahmad *et al*. (2006) also found that LER of sorghum + *dhaincha* intercropping system was 1.64 and concluded that all intercropping systems gave higher LER than their respective sole crops.

Rabi season

Wheat yield and yield attributes

Increase in nitrogen level from 75 to 150 kg/ha significantly increased the wheat grain yield and yield attributes (Table 2). The wheat grain yield and biological yield were found 30.1 and 14.2% more in *dhaincha* sole at 60 cm followed by wheat over sole sorghum at 25 cm spacing followed by wheat cropping system. Wheat followed by all intercropping treatments yielded higher than sole crop. Tanwar *et al* (2014) also found the 19.9% improvement in wheat yield in sorghum+ *dhaincha* (green manuring) - wheat cropping system over sole sorghum - wheat system. This may be due to nitrogen fixation and availability of nitrogen after decomposition and mineralization of nitrogen rich green manure *dhaincha*. Among the intercropping treatments 1:1 row ratio of *dhaincha* and sorghum at 30 cm spacing followed by wheat was observed with significantly higher wheat seed and biological yield. But this treatment was having 4.2% less and 24.8% higher seed yield as compared to sole *dhaincha* followed by wheat and sole sorghum

Table 3 Effect of different treatments on wheat equivalent yield, economic performance and production efficiency of whole cropping systems (Pooled data of two years).

Treatments	Whole system (*Dhaincha* + Sorghum fodder followed by wheat)						
	Wheat equivalent yield (WEY)(t/ha)	Total cost (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C	System profitability (₹/ha/day)	Production efficiency (ton WEY/ ha/day)
Dhaincha sole at 60 cm spacing fb wheat	6.46	77281	104688	68068	1.35	230	2.18
Sorghum fodder sole at 25 cm Spacing fb wheat	6.02	81033	93931	53558	1.16	181	2.03
1:1 row ratio of *dhaincha* and sorghum at 30 cm spacing fb wheat	7.22	86204	114171	71402	1.32	241	2.44
1:2 row ratio of *dhaincha* and sorghum at 20 cm spacing fb wheat	6.88	88932	108377	62881	1.22	212	2.32
1:2 row ratio of *dhaincha* and sorghum at 30 cm spacing fb wheat	7.1	85986	111639	69088	1.30	233	2.40
1:3 row ratio of *dhaincha* and sorghum at 22.5 cm spacing fb wheat	6.95	87970	108762	64228	1.24	217	2.35
1:3 row ratio of *dhaincha* and sorghum at 30 cm spacing fb wheat	6.81	85877	106580	64139	1.24	217	2.30
1:4 row ratio of *dhaincha* and sorghum at 24 cm spacing fb wheat	6.64	87365	104581	60651	1.20	205	2.24
2:3 row ratio of dhaincha pair at 45 cm spacing and 3rows of sorghum in 90 cm spacing between *dhaincha* pairs fb wheat	6.87	86893	109340	65882	1.26	223	2.32
2:4 row ratio of dhaincha pair at 60 cm spacing and 4rows of sorghum in 120 cm spacing between *dhaincha* pairs fb wheat	6.82	85986	108236	65686	1.26	222	2.30
SEm ±	0.092						
CD (P=0.05)	0.274						

followed by wheat, respectively.

Total number of tillers/mrl, number of effective tillers/mrl, spike length, spikelets/spike, grains/spike and test weight were found highest with a increase of 24.8, 15.8, 19.1, 8.4, 5.8 and 3.7%, respectively, when wheat was sown after sole crop of *dhaincha* as compared to wheat sown after sole sorghum crop (Table 2). Tanwar *et al*. (2014) also reported that *kharif* intercropping of legumes with sorghum or legume alone markedly influenced the succeeding wheat crop in terms of yield attributes as compared to sole sorghum in *kharif*. Among intercropping treatments 1:1 row ratio of *dhaincha* and sorghum at 30 cm spacing followed by wheat was found with highest total number of tillers/mrl (120.4), number of effective tillers/mrl (100.8), spike length (10.8 cm), spikelets/spike (21.8), grains/spike (42.1) and test weight (43.9g) with reduction of (0.8, 2.6, 3.4, 0.4, 0.2 and 0.9%) and increment of (23.9, 12.7, 14.9, 7.9, 5.5 and 2.8%) over wheat sown after sole crop of *dhaincha* and sole crop of sorghum, respectively. Similar findings were also reported by Kumpawat and Rathore (2003).

Whole system (Dhaincha + sorghum - wheat)

Wheat equivalent yield

An increase of 11.8 and 19.9% in wheat equivalent yield over sole *dhaincha* followed by wheat and sole sorghum followed by wheat, respectively, with the highest wheat equivalent yield (7.2 tonnes/ha) was observed with 1:1 row ratio of *dhaincha* and sorghum at 30 cm spacing followed by wheat. It was statistically at par with 1:2 and 1:3 row ratio of *dhaincha* and sorghum, respectively at 30 and 22.5 cm spacing followed by wheat (Table 3). The reason for this highest wheat equivalent yield in these treatments could be attributed to higher *dhaincha* and wheat seed yield in these treatments. These results were in conformity with findings of Kumar and Prasad (1999).

Economics

Sole *dhaincha* grown for seed followed by wheat was found with higher net return, B: C, system profitability and production efficiency as compared to sole sorghum for fodder followed by wheat cropping system (Table 3). The possible reason was lowest cost of production and highest wheat and *sesbania* yield in sole *dhaincha*-wheat system as compared to other treatments. Among intercropping systems, 1:1 row ratio of *dhaincha* and sorghum at 30 cm spacing followed by wheat was observed as most profitable cropping system with net return of (` 71402), B:C ratio (1:32), system profitability (` 241/ha/day) and production efficiency (2.44 tonnes WEY/ha/day) closely followed by 1:2 row ratio of *dhaincha* and

Table 4 Indices on the basis of energy use efficiency influenced by different treatments (Pooled data over two years)

Treatment	System input energy (× 10^3 MJ/ha)	System output energy (× 10^3 MJ/ha)	System net energy return (× 10^3 MJ/ha)	Energy ratio	Energy productivity (kg WEY/MJ/ha)	Energy intensiveness (MJ/₹)
Dhaincha sole at 60 cm spacing fb wheat	21.7	433.8	411.6	20.0	297.7	5.61
Sorghum fodder sole at 25 cm Spacing fb wheat	28.0	910.2	882.3	32.5	215.0	11.23
1:1 row ratio of *dhaincha* and sorghum at 30 cm spacing fb wheat	25.3	744.7	718.8	29.4	285.4	8.63
1:2 row ratio of *Dhaincha* and sorghum at 20 cm spacing fb wheat	26.7	842.7	816.0	31.6	257.7	9.48
1:2 row ratio of *dhaincha* and sorghum at 30 cm spacing fb wheat	25.4	762.2	737.2	30.0	279.5	8.87
1:3 row ratio of *dhaincha* and sorghum at 22.5 cm spacing fb wheat	26.2	840.3	814.1	32.1	265.3	9.55
1:3 row ratio of *dhaincha* and sorghum at 30 cm spacing fb wheat	25.3	768.9	743.6	30.4	269.2	8.95
1:4 row ratio of *dhaincha* and sorghum at 24 cm spacing fb wheat	26.0	820.8	794.8	31.6	255.4	9.40
2:3 row ratio of dhaincha pair at 45 cm spacing and 3rows of sorghum in 90 cm spacing between *dhaincha* pairs fb wheat	25.8	752.8	727.0	29.2	266.3	8.66
2:4 row ratio of dhaincha pair at 60 cm spacing and 4rows of sorghum in 120 cm spacing between *dhaincha* pairs fb wheat	25.0	759.2	734.2	30.4	272.8	8.83

WEY= Wheat 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.

Table 5 Change in soil fertility status after two year cycle and apparent nutrient productivity under different treatments

Treatment	After two years of completion of crop cycle (2011-13)				
	OC (%)	Available nutrients (kg/ha)			Apparent nutrient use productivity (kg WEY/ha-kg)
		N (kg/ha)	P (kg/ha)	K (kg/ha)	
Dhaincha sole at 60 cm spacing fb wheat	0.42	215	26.4	278	19.8
Sorghum fodder sole at 25 cm spacing fb wheat	0.38	195	21.0	259	15.6
1:1 row ratio of *dhaincha* and sorghum at 30 cm spacing fb wheat	0.41	208	25.5	275	20.3
1:2 row ratio of *dhaincha* and sorghum at 20 cm spacing fb wheat	0.41	202	23.8	265	19.4
1:2 row ratio of *dhaincha* and sorghum at 30 cm spacing fb wheat	0.40	205	24.6	270	20.0
1:3 row ratio of *dhaincha* and sorghum at 22.5 cm spacing fb wheat	0.40	200	23.6	264	19.5
1:3 row ratio of *dhaincha* and sorghum at 30 cm spacing fb wheat	0.39	198	23.5	263	19.2
1:4 row ratio of *dhaincha* and sorghum at 24 cm spacing fb wheat	0.39	197	23.0	261	18.7
2:3 row ratio of dhaincha pair at 45 cm spacing and 3rows of sorghum in 90 cm spacing between *dhaincha* pairs fb wheat	0.41	206	25.0	273	19.3
2:4 row ratio of dhaincha pair at 60 cm spacing and 4rows of sorghum in 120 cm spacing between *dhaincha* pairs fb wheat	0.40	203	24.1	268	19.2
Initial status	0.39	194	22.0	258	

sorghum at 30 cm spacing followed by wheat. The highest *sesbania* and wheat grain yield obtained in this treatment may be the reason for higher economics. These findings were in accordance with the results of Bhushan and Omprakash (2001).

Energetics

The system input energy, output energy, net energy return, energy ratio and energy intensiveness were found highest with sole sorghum followed by wheat cropping system (Table 4). High input requirement in the form of labour, nitrogen and chemicals and high value of the energy equivalent per kg of green sorghum fodder having very high yield potential could be the possible reason for highest energy based indices in this system. Among the intercropping systems, higher input energy (26.7×10^3 MJ/ha), system output energy (842.7×10^3 MJ/ha), system net energy return (816.0×10^3 MJ/ha), energy ratio (31.6) and energy intensiveness (9.48) were observed with 1:2 row ratio of *dhaincha* and sorghum at 20 cm spacing followed by wheat and this treatment was closely followed by 1:3 row ratio of *dhaincha* and sorghum at 22.5 cm spacing followed by wheat cropping system. The maximum number of rows of both the crops in these treatments might have utilized all the resources very efficiently with maximum system output energy levels. Similar results were also reported by Singh *et al.* (2008) and Tuti *et al.* (2013), who reported highest output energy (213.7×10^3 MJ/ha) with pigeonpea – wheat system.

Soil fertility status

After completion of two years of study *dhaincha* sole followed by wheat cropping system was found with maximum soil organic carbon, N, P and K content having an increase of 7.6, 10.8, 20.0 and 7.7%, respectively, over their initial status. (Table 5). Several workers have observed organic carbon content of the soil increased with the application of different organic materials and inclusion of leguminous plants in cropping systems (Kumar and Balyan. 2001 and Singh *et al.* 2008). The possible reason for the improvement of organic carbon, nitrogen and other nutrient was the number of *dhaincha* rows which had added the organic matter in soil in large amount. These results support the findings of Kumar *et al.* 2012. Among the intercropping treatments 1:1 row ratio of *dhaincha* and sorghum at 30 cm spacing followed by wheat cropping system was observed as most improved cropping system having highest apparent nutrient use productivity of 20.3 kg WEY/ha-kg.

Thus, it can be inferred that sole *dhaincha* for seed purpose succeeded by wheat was more profitable over sorghum- wheat crop rotation. From sustainability point of view to encourage the farmers for seed production of *dhaincha* and to get maximum net return, the *dhaincha* sown at 60 cm spacing intercropped with one row of sorghum followed by wheat and *dhaincha* sown at 90 cm spacing intercropped with two rows of sorghum followed by wheat are most economical crop rotations.

REFERENCES

Ahmad A U H, Ahmad R , Mahmood N and Nazir M S. 2006. Competitive performance of associated forage crops grown in different forage sorghum-legume intercropping systems. *Pakistan Journal of Agricultural Science* **43**(1-2): 25–31.

Bhushan L S and Omprakash. 2001. Performance of wheat (*Triticum aestivum*) succeeding different *kharif* crops in semi-arid climate- an approach towards reducing chemical fertilizer dependence. *Indian Journal of soil conservation* **29**(1): 33–8.

Chopra S L and Kanwar J S.1991. Analytical Agricultural Chemistry. Kalyani Publishers, New Delhi.

Devasenapathy P, Senthilkumar G and Shanmugam P M. 2009. Energy management in crop production. *Indian Journal of Agronomy* **54**(1): 50–90.

ICAR. 2012. Forage crops and grasses. (*In*) *Handbook of Agriculture*, pp 1353–417. ICAR, New Delhi.

Kujur S, Ahmad S, Srivastava G P and Singh C S. 2010. Performance of (*Cajanus cajan*) intercropping as influenced by row ratios and duration of fingermillet (*Elusine coracana*) cultivars. *Indian Journal of Agronomy* **55**(3): 209–14.

Kumar Sanjay and Prasad N K. 1999. Soil fertility and yield as influenced by different legume-wheat (*Triticum aestivum*) sequences. *Indian Journal of Agronomy* **44**(3): 488–92.

Kumar A and Balyan J S. 2001. Grain production of wheat (*Triticum aestivum*) and N and P balance sheet in soil under sorghum (*Sorghum bicolor*) + cowpea (*Vigna unguiculata*) – wheat crop sequence. *Indian Journal of Agronomy* **46**(2): 198–203.

Kumar S, Dahiya R, Kumar P, Jhorar B S and Phogat V K. 2012. Long term effect of organic materials and fertilizers on soil properties in pearlmillet-wheat cropping system. *Indian Journal of Agricultural Research* **46**(2): 161–6.

Pal M, Singh K A and Ahlawat I P S. 1985. Cropping system research: Concept, needs and directions. (*In*) *Proceedings of the National symposium by Indian Society of Agronomy*, CSSRI, Karnal, 3-5 April 1985, pp 1– 45.

Panse V G and Sukhatme P U. 1995. Statistical Methods for Agricultural Workers, ICAR, New Delhi.

Sankaranarayanan K, Olaimalai A and Sankaran N. 2005. Intercropping of legumes in fodder sorghum-a review. *Agricultural Review* **26**(3): 217–22.

Singh Umed, Saad A A and Singh S R. 2008. Production potential, biological feasibility and economic viability of maize (*Zea mays*)-based intercropping systems under rainfed conditions of Kashmir valley. *Indian Journal of Agricultural Sciences* **78**(12): 1 023–7.

Singh N B, Singh R S and Verma K K. 2013. Intensification of rice (*Oryza sativa*) based cropping sequences with summer mungbean (*Vigna radiata*) in eastern Uttar Pradesh. *Indian Journal of Agronomy* **58**(2): 133–6.

Tanwar S P S, Rao S S, Regar P L, Datt Shiv, Kumar P, Jodha B S, Santra P, Kumar Rajesh and Ram Rameshwar 2014. Improving water and land use efficiency of fallow-wheat system in shallow Lithic Calciorthid soils of arid region: Introduction of bed planting and rainy season sorghum- legume intercropping. *Soil and Tillage Research* 138: 44–55.

Tuti M D, Mahanta D, Bhattacharyya R, Pandey B M, Bist J K and Bhatt J C. 2013. Productivity, economics and energetic of Pigeonpea (*Cajanus cajan*) – based cropping system in mid hills of north west Himalaya. *Indian Journal of Agronomy* **58**(3): 303–8.

Venkateswarlu B and Shanker A K. 2009. Climate change and agriculture: Adaptation and mitigation strategies. *Indian Journal of Agronomy* **55** (2): 226–30.

Verma S S, Joshi Y P and Sexena S C. 2005. Effect of row ratio of fodder sorghum (*Sorghum bicolour*) in Pigeonpea (*Cajanus cajan*) intercropping systems on productivity, competition functions and economics under rainfed conditions of north India. *Indian Journal of Agronomy* **50**(2): 123–5.