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Relative Yield, Competition, Land Use and Economic Performance of Chickpea-based Intercropping Systems

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ABSTRACT

Background: Chickpea is the third-most important food legume in the world. Chickpea is less remunerative than raya, linseed and fenugreek. Hence there is a gradual shift in cropping patterns from sole chickpea to its intercropping with raya, linseed and fenugreek. Intercropping offers potential advantages over sole cropping. Since information on the relative yield, competition, land use and economics of chickpea intercropping with raya, linseed and fenugreek is lacking, hence the present experiment was undertaken.

Methods: A field experiment was performed at CCSHAU, Hisar, during two consecutive winter seasons, *i.e.*, 2020-21 and 2021-22, following a randomized block design comprising nineteen treatments, replicating thrice. The study was aimed to evaluate the chickpea-based intercropping in row replacement system with fenugreek, linseed and raya as an intercrop with row ratio of 4:4, 5:3, 6:2, 3:5 and 2:6 for chickpea + intercrop along with their sole crop.

Result: Chickpea + fenugreek (6:2) intercropping was found utmost efficient and suitable, having significantly higher LER (1.20), CEY (2396 kg/ha), LUE (119.3), ATER (1.18), A (0.53), RCC (4.18), MAI (18838), SPI (2208), IAI (34.6), net return (Rs. 96,170/ha) and benefit cost ratio (3.79).

Key words: Chickpea, Fenugreek, Intercropping, Linseed, Raya.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the third-most important food legume in the world. India and Pakistan are the two major countries contributing more than 75% of the world's produced chickpea annually. India alone has nearly 69.2% of the world's acreage and 70.1% of the world's production of a gram. In India, chickpea with a production of 9.94 million tones and productivity of 1040 kg/ha, is grown over an area of 9.55 million ha (Anonymous, 2022). However, chickpea is less remunerative than Indian raya, linseed and fenugreek. Hence there is a gradual shift in cropping patterns from sole chickpea to its intercropping with raya, linseed and fenugreek and in extreme cases, to sole cropping of the intercrops. Intercropping, a common practice in developing countries is crucial for multiple cropping systems. It offers potential advantages over monoculture by improving productivity through the efficient use of resources, including water, fertilizer, solar energy, land, money and energy, it offers potential advantages over monoculture. To maintain soil health, protect the environment and satisfy the daily food and animal feed needs, existing cropping systems must be diversified to produce higher yields and returns. The success of intercrops compared to a pure crop can be determined by planting date, ultimate density, resource availability and intercropping models (Mazaheri *et al*., 2006).

Because of their different morphologies, overlapping development cycles and similar environmental requirements, intercropping of chickpea with linseed, Indian raya and fenugreek is effective. Such intercropping techniques are common in Uttar Pradesh, Rajasthan, Bihar, Haryana, Madhya Pradesh and Maharashtra. Raya, the world's third most crucial oilseed crop after soybean and palm oil, contributes 28.6% of the total oilseed production. Linseed having 33-47 per cent of the seed oil, is grown mainly for oil. Linseed farming is expanding due to the urban population's rising health consciousness. Fenugreek is considered both a spice and a crop of legumes. The intercrops did not compete with the main crop for vertical and horizontal resources because of different growth habits and rooting depths. The intercropping system may have advantages, including higher profitability, increased production per unit area per unit time, improved soil fertility, effective resource utilization and lessening damage from weeds, pests and diseases (Ghosh, 2004). However, in an intercropping system, the geographical configuration and plant population significantly impact the component crops' relative competitiveness and overall output. Since information on the relative yield, competition, land use and economics of these systems is lacking, hence the present experiment was undertaken.

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MATERIALS AND METHODS

During the *Rabi* seasons of 2020-21 and 2021-22, a field experiment was conducted at the crop physiology field research area of CCS Haryana Agricultural University Hisar, Haryana, India (29°10′N latitude, 75°46′E longitude and 215.2 M altitude) in a randomized block design, replicated three times with nineteen treatments to evaluate chickpea based intercropping systems taking fenugreek, linseed and raya as an intercrop with planting patterns of chickpea + intercrop with row ratio of 4:4, 5:3, 6:2, 3:5 and 2:6, respectively. The soil in the field had sandy loam texture, pH of 7.7 that was slightly alkaline, low organic carbon (0.38%), poor in available nitrogen (195 kg/ha), medium in available phosphorus (13.2 kg/ha) and rich in available potassium (252 kg/ha). The maximum and minimum temperature during the crop study period was pleasant for the growth and development of crops. Sowing sole and intercrops were done at a 30 cm row-to-row distance. In intercropping treatments, chickpea rows were replaced with intercrops as per treatments in various row ratios of chickpea + intercrop varying from 4:4, 5:3, 6:2, 3:5 and 2:6. The gross plot size was 7.2 m × 3.5 m. Chickpea variety HC 5 was intercropped with linseed (K 2), fenugreek (MH 57) and raya (RH 725) in the experiment. The basal doses of nutrients were given as per RDF of chickpea recommended by CCS HAU, Hisar. Later on, an additional dose of nitrogen was given to each crop as per their requirements after the first irrigation. Two times weeding was done manually. Irrigation was given twice at 40-45 and 85-90 DAS. The sowing of the experiment was done on 5th November and 30th October during the first and second year of the investigation, Crops were grown as per package of practices recommended by CCS HAU, Hisar, India. Based on the market price, the economic output of various crops was transformed into chickpea equivalent yield (CEY). The different intercropping indices. *i.e*. relative crowding coefficient (RCC) (Banik *et al*., 2006), aggressivity (A) (Dhima *et al*., 2007), competitive ratio (CR) (Esmaeili *et al*., 2011), land equivalent ratio (LER) (Adetiloye *et al*., 1983), area time equivalent ratio (ATER) (Banik, 1996), income equivalent ratio (IER) and monetary advantage index (MAI) Poddar *et al.* (2017), land use efficiency (LUE) (Ram *et al*., 2012), intercropping advantage index (IAI) (Banik *et al*., 2000), relative net returns index (RNRI) (Jain and Rao, 1980) and chickpea equivalent yield (CEY) (Willey and Rao, 1980 and Padhi *et al*., 2010) were calculated to examine the relative yield, competition, land use and economic performance of chickpea-based intercropping systems in replacement series. All the experimental data for various characters were statistically analyzed by the method of analysis of variance (ANOVA) as described by Panse and Sukhatme (1985) using OPSTAT software.

RESULTS AND DISCUSSION

Chickpea seed yield

Intercropping of fenugreek, linseed and raya in replacement series with chickpea has significantly reduced the chickpea seed yield compared to sole chickpea (Table 1). Irrespective of row ratios, raya intercropping in chickpea recorded a significantly higher seed yield loss of 84.5 per cent, while fenugreek and linseed intercropping reduced chickpea seed yield by 71.4 and 71.8 per cent, respectively, compared to sole chickpea crop. Chickpea intercropped with any crops in row ratios of 6:2 and 2:6 recorded significantly lower and higher seed yield loss over sole chickpea crops, respectively. Among all intercrops tested in chickpea, linseed, followed by fenugreek, was found most successful as an intercrop in chickpea in all row ratios of planting considered (Table 1). In contrast, raya as an intercrop in chickpea proved unsuccessful. In their studies, Biradar *et al*. (2015); Upadhyay *et al*. (2012) and Tanwar *et al.* (2011) also indicated a similar viewpoint. Aggressivity, RCC and ATER, among other intercropping indicators, all showed positive correlations with chickpea seed output, with respective “r” values of 0.68, 0.81 and 0.72.

Intercrop yield

Table 1 indicated that irrespective of row ratios, the seed yield of all intercrops declined significantly over their sole crop. Among planting, the geometries row ratio (chickpea: intercrop) of 2:6 and 6:2 were recorded with lower and higher yield loss than their sole crop, respectively, for all intercrops. The seed yield reduction over sole crop was 26.5-66.0, 29.7-68.7 and 27.9-52.8 per cent, respectively, for fenugreek, linseed and raya crop. Aggressivity, RCC and ATER were positively associated with intercrop seed yield with respective “r” values of 0.68, 0.75 and 0.73. Similar trends of reduction in seed yield of intercrops over their respective sole crop also highlighted by Singh *et al*. (2019) for chickpea + raya intercropping. Vasu *et al*. (2013) for chickpea + linseed intercropping and Poddar *et al.* (2017) for chickpea + fenugreek intercropping.

Chickpea equivalent yield

In comparison to growing just chickpea, intercropping with other crops significantly reduced the output of chickpea equivalents. Raya and fenugreek, which were intercrops, had considerably greater CEY under solo and intercropping systems (Table 1). This may be because they had a higher market price and yield than other crops. For different intercrops tested with chickpea, higher CEY (kg/ha) of 2396, 2177 and 2331 was recorded with chickpea + fenugreek (6:2), chickpea + linseed (6:2) and chickpea + raya (4:4), respectively. Similar results were obtained by Singh *et al.* (2019).

Relative crowding coefficient

Intercropping systems had a significant impact on RCC. Chickpea intercropped with fenugreek and linseed was recorded higher RCC values with all row ratios except 4:4, which shows chickpea higher competitive ability and relative dominance over intercrops (Table 2). Chickpea + raya intercropping at all row ratios resulted in higher RCC for raya over chickpea. Higher RCC for chickpea was recorded

Table 1: Yield performance and Land use efficiency of chickpea based intercropping systems.

Treatments	Seed yield (kg/ha)		Chickpea equivalent	Land equivalent ratio (LER)			Land use efficiency (LUE)
	Chickpea	Inter crop	yield (kg/ha)	Chickpea	Inter crop	System	
Sole chickpea	1851		1851				
Sole fenugreek		2159	2540				
Sole linseed		1708	1843				
Sole raya		3040	2771				
Chickpea + Fenugreek (4:4)	946	1011	2137	0.52	0.48	1.00	98.9
Chickpea + Fenugreek (5:3)	1282	869	2305	0.70	0.43	1.13	112.0
Chickpea + Fenugreek (6:2)	1528	734	2396	0.83	0.37	1.20	119.3
Chickpea + Fenugreek (3:5)	694	1375	2313	0.39	0.69	1.08	106.3
Chickpea + Fenugreek (2:6)	529	1587	2392	0.30	0.80	1.10	108.1
Chickpea + Linseed (4:4)	1080	944	2098	0.58	0.55	1.13	112.8
Chickpea + Linseed (5:3)	1327	765	2153	0.70	0.44	1.14	113.6
Chickpea + Linseed (6:2)	1600	534	2177	0.85	0.30	1.16	115.8
Chickpea + Linseed (3:5)	681	1049	1812	0.38	0.61	0.98	98.5
Chickpea + Linseed (2:6)	522	1200	1817	0.29	0.71	1.00	99.4
Chickpea + Raya (4:4)	566	1936	2331	0.30	0.63	0.94	92.7
Chickpea + Raya (5:3)	588	1613	2060	0.32	0.55	0.86	85.0
Chickpea + Raya (6:2)	661	1435	1970	0.35	0.47	0.83	81.7
Chickpea + Raya (3:5)	380	2099	2294	0.21	0.70	0.91	89.4
Chickpea + Raya (2:6)	287	2189	2283	0.16	0.74	0.90	88.1
CD at 5%	224		650	0.13	0.19	0.09	9.5
SEm±	77		225	0.04	0.06	0.02	3.2

Table 2: Intercropping indices to evaluate relative competitiveness of chickpea based intercropping systems.

Treatments	Ater	Aggressivity (A)		RCC			Competitive ratio	
		Chickpea	Inter crop	K_{CP} (Chickpea)	K_{IM} (Intercrop)	System K= K_{MI} * K_{IM}	Chickpea	Intercrop
Sole chickpea	-	-	-	-	-	-	-	-
Sole fenugreek	-	-	-	-	-	-	-	-
Sole linseed	-	-	-	-	-	-	-	-
Sole raya	-	-	-	-	-	-	-	-
Chickpea + Fenugreek (4:4)	0.97	0.02	-0.02	1.39	1.55	2.15	1.19	0.97
Chickpea + Fenugreek (5:3)	1.11	0.27	-0.27	1.45	1.40	2.03	1.02	1.04
Chickpea + Fenugreek (6:2)	1.18	0.53	-0.53	2.10	1.99	4.18	0.81	1.31
Chickpea + Fenugreek (3:5)	1.05	-0.28	0.28	1.25	0.19	0.24	1.06	1.20
Chickpea + Fenugreek (2:6)	1.06	-0.52	0.51	1.39	0.40	0.56	1.35	1.16
Chickpea + Linseed (4:4)	1.12	0.01	-0.01	1.57	2.25	3.53	1.13	0.94
Chickpea + Linseed (5:3)	1.13	0.27	-0.27	1.84	1.75	3.22	1.04	1.14
Chickpea + Linseed (6:2)	1.14	0.56	-0.56	3.26	1.42	4.32	1.01	1.10
Chickpea + Linseed (3:5)	0.98	-0.23	0.23	1.19	1.14	1.35	1.08	1.24
Chickpea + Linseed (2:6)	0.99	-0.46	0.46	1.26	0.84	1.05	1.24	0.86
Chickpea + Raya (4:4)	0.90	-0.16	0.16	0.44	2.18	0.96	0.49	2.06
Chickpea + Raya (5:3)	0.83	-0.00	0.00	0.30	2.17	0.65	0.36	3.03
Chickpea + Raya (6:2)	0.80	0.14	-0.14	0.18	2.91	0.53	0.25	4.07
Chickpea + Raya (3:5)	0.87	-0.35	0.35	0.48	1.52	0.73	0.53	2.27
Chickpea + Raya (2:6)	0.85	-0.51	0.51	0.66	1.09	0.71	0.68	2.02
CD at 5%	0.11	0.20	0.21	0.99	0.39	0.48	0.58	0.93
SEm±	0.03	0.07	0.07	0.34	0.13	0.16	0.20	0.32

with 6:2 row ratio in the case of intercropping with fenugreek (2.10) and linseed (3.26), which showed the relative advantage of intercropping over sole chickpea crop (Table 2). Among all intercropping systems, chickpea + raya intercropping was found non advantageous as RCC of the system was less than one, while chickpea intercropping with fenugreek and linseed was recorded with system RCC values more than one at all row ratios tested except chickpea + fenugreek in 3:5 and 2:6 row ratio. Chickpea + linseed (6:2) closely followed by chickpea + fenugreek (6:2) recorded with significantly higher system RCC values of 4.62 and 4.18, respectively. Poddar *et al.* (2017) have also reported RCC higher than one in the case of chickpea-based intercropping systems. RCC was positively correlated with chickpea and intercrop seed yield with respective "r" values of 0.81 and 0.75.

Competitive ratio

Table 2 resulted that intercropping treatments had a considerable impact on competitive ratio. Fenugreek and linseed as intercrop recorded higher CR values compared to chickpea at all row ratios except 4:4 and 2:6. Chickpea compared to raya recorded lower CR values at all row ratios in intercropping systems, which shows the more competitive nature of raya over chickpea. Among intercrops, raya followed by fenugreek and linseed recorded higher CR, which showed a higher competitive nature of raya compared to other crops against chickpea crop. Among all intercropping systems, chickpea + fenugreek (2:6) was recorded significantly higher $CR_{chickpea}$ (1.35) closely followed by chickpea + linseed (2:6) with $CR_{chickpea}$ (1.24), while chickpea + raya (6:2) was recorded with significantly higher $CR_{intercrop}$ (4.07) closely followed by chickpea + raya (5:3) (3.03). Vasu *et al.* (2013) found that the highest competition ratio (1.23) of chickpea was observed in chickpea + linseed intercropping system when grown at 3:3 row proportion. Similar type of variations in CR of main and intercrops was also observed by Willey and Rao (1980).

Aggressivity

Aggressivity (A) was significantly affected by intercropping treatments. Chickpea recorded positive A values with 4:4, 5:3 and 6:2 row ratios, while intercrop recorded positive A values with 3:5 and 2:6 row ratios when it was intercropped with fenugreek and linseed crop. Raya as an intercrop showed positive A values with all row combinations except 6:2., which shows the higher aggressivity or dominance of raya over chickpea in intercropping systems. Among all intercropping systems, chickpea + fenugreek (6:2), chickpea + linseed (6:2) and chickpea + raya (2:6) were recorded with significantly higher A values both for chickpea (+ 0.53, +0.56 and -0.51) and intercrop (-0.53, -0.56 and +0.51), respectively (Table 2). Seed yield of chickpea and intercrop was positively correlated with aggressivity with "r" value of 0.68. Vasu *et al.* (2013) has also reported that crops having higher number of rows in intercropping combination showed higher dominance over other crop and recorded with positive A values.

Land equivalent ratio

Table 1 illustrated that LER for chickpea, intercrop and system were significantly affected by intercropping systems. Irrespective to intercrops, LER for chickpea crop was declined with decline in plant population compared to intercrop. Higher LER for chickpea (0.83, 0.85 and 0.35) was recorded with row ratio of 6:2 when chickpea was intercropped with fenugreek, linseed and raya, respectively, which may be due to higher chickpea yield in these intercropping treatments compared to others. Higher LER for intercrop (0.80, 0.71 and 0.74) was recorded with row ratio of 2:6 when chickpea was intercropped with fenugreek, linseed and raya, respectively. Intercropping of chickpea with fenugreek and linseed with all row ratios except chickpea+ fenugreek (4:4), chickpea + linseed (3:5) and chickpea + linseed (2:6) was recorded with LER values more than one, hence proved more economical than sole planting of chickpea. Chickpea intercropping with raya in all row combinations recorded LER less than one, hence concluded uneconomical over sole chickpea crop. Among all the intercropping systems, chickpea + fenugreek (6:2) closely followed by chickpea + linseed (6:2) and chickpea + linseed (5:3) recorded significantly higher LER (1.20). Vasu *et al.* (2013) and Poddar *et al.* (2017) also recorded variation in terms of LER among intercropping systems, resulting in intercropping of chickpea with linseed and fenugreek was profitable, having system LER values more than one. Similar conclusions were also drawn by Padhi *et al*. (2010); Ahlawat and Gangaiah (2010); Dhaka *et al.* (2015) and Hossain *et al*. (2000).

Area-time equivalency ratio

Significant variation regarding ATER was obtained among intercropping systems. Intercropping of chickpea with fenugreek and linseed with all row ratios except chickpea+ fenugreek (4:4), chickpea + linseed (3:5) and chickpea + linseed (2:6) was recorded with ATER values more than one, hence proved more advantageous than sole planting of chickpea. Chickpea intercropping with raya in all row combinations recorded ATER less than one, hence found uneconomical over sole chickpea. Among all the intercropping systems, chickpea + fenugreek (6:2) closely followed by chickpea + linseed (6:2) and chickpea + linseed (5:3) recorded significantly higher ATER (1.18) (Table 2). ATER was found positively correlated with chickpea seed yield (r= 0.72). Similar trend of observation about ATER was also reported by Poddar *et al.* (2017) and Dhaka *et al.* (2014) for different chickpea based intercropping systems.

Land use efficiency

Significant variation among intercropping systems was found regarding LUE. Chickpea intercropping with fenugreek and linseed resulted in LUE of more than a hundred in all intercropping systems except chickpea + fenugreek (4:4), chickpea + linseed (3:5) and chickpea + linseed (2:6), which showed better and efficient use of land as a resource. Chickpea intercropped with raya in all row combinations

Table 3: Economic evaluation of chickpea based intercropping systems.

Treatments	VC (Rs/ha)	TC (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	BCR	VCR	Per day return (Rs./ha/day)	MAI (Rs/ha)	RNRI	REE	Intercropping advantage index (IAI)	Income equivalent ratio (IER)
Sole chickpea	17453	34475	119821	85346	3.48	2.48	588.6					
Sole fenugreek	17348	34345	133856	99511	3.73	2.90	696.6					
Sole linseed	19903	37470	97078	59608	2.59	1.59	399.5					
Sole raya	26923	58338	153062	94724	2.62	1.62	668.9					
Chickpea + Fenugreek (4:4)	17403	34410	115016	80606	3.34	2.34	536.4	1248	1.18	0.25	0.16	1.25
Chickpea + Fenugreek (5:3)	17413	34428	125469	91041	3.64	2.64	606.6	12105	1.26	0.39	15.61	1.39
Chickpea + Fenugreek (6:2)	17428	34445	130615	96170	3.79	2.79	641.9	18838	1.31	0.47	34.66	1.47
Chickpea + Fenugreek (3:5)	17388	34393	123642	89250	3.60	2.60	595.5	4024	1.27	0.38	8.41	1.38
Chickpea + Fenugreek (2:6)	17373	34380	127398	93018	3.71	2.71	622.9	4731	1.30	0.39	13.90	1.39
Chickpea + Linseed (4:4)	18680	35973	112824	76851	3.13	2.13	510.1	12805	1.18	0.20	13.96	1.20
Chickpea + Linseed (5:3)	18370	35600	117525	81925	3.30	2.30	546.9	13256	1.19	0.24	16.11	1.24
Chickpea + Linseed (6:2)	18065	35225	118989	83764	3.37	2.37	559.2	15133	1.20	0.27	19.34	1.12
Chickpea + Linseed (3:5)	18985	36348	97020	60672	2.67	1.67	400.2	97	1.04	-0.00	-0.43	1.13
Chickpea + Linseed (2:6)	19290	36723	96863	60141	2.63	1.63	397.5	249	1.04	-0.03	5.26	0.97
Chickpea + Raya (4:4)	22190	46408	129463	83055	2.79	1.79	548.7	-6829	1.44	0.35	-6.80	1.35
Chickpea + Raya (5:3)	21003	43425	114352	70927	2.63	1.63	469.7	-17820	1.25	0.13	-3.35	1.13
Chickpea + Raya (6:2)	19820	40443	109353	68911	2.70	1.70	456.0	-20444	1.17	0.11	16.09	1.11
Chickpea + Raya (3:5)	23373	49388	126829	77441	2.57	1.57	509.4	-9945	1.46	0.29	-15.92	1.29
Chickpea + Raya (2:6)	24555	52373	126584	74212	2.41	1.41	488.4	-13778	1.49	0.24	-17.45	1.24
CD at 5%			33418	21305	0.67	0.63	151.3	6909	0.32	0.20	5.56	0.35
SEm±			11604	7398	0.23	0.22	52.6	2372	0.11	0.06	1.89	0.12

recorded LUE less than a hundred, hence found uneconomical (Table 1). Among all intercropping systems, chickpea + fenugreek (6:2), closely followed by chickpea + linseed (6:2), reported significantly higher LUE (119.3). Singh *et al.* (2021) also reported 6.12 per cent higher land use efficiency in chickpea + linseed (4:2) compared to sole planting of chickpea might be due to increased light interception, reduced water evaporation that improved conservation of the soil moisture in intercropping treatments compared to sole cropping.

Monetary advantage index

Table 3 indicated that intercropping systems significantly affected MAI. Intercropping of chickpea with fenugreek and linseed recorded positive MAI values with all row combinations, while chickpea + raya intercropping resulted negative MAI values at all row ratios tested, which showed relative monitory advantage of chickpea + fenugreek/linseed over chickpea + raya intercropping. Among all intercropping systems, chickpea + fenugreek (6:2) closely followed by chickpea + linseed (6:2) recorded significantly higher (Rs. 18,838/ha) MAI. Higher MAI for various chickpea based intercropping systems over sole chickpea planting was also reported by Poddar *et al.* (2017).

Intercropping advantage index

Chickpea intercropping with fenugreek and linseed recorded positive IAI at all row ratio combinations except chickpea + linseed (3:5), while in case of chickpea + raya intercropping the negative values of IAI was obtained with all row ratios except 6:2 (Table 3). It showed relative advantage of fenugreek and linseed intercropping in chickpea compared to raya as intercrop. Chickpea intercropped with fenugreek recorded higher IAI with all row ratios except 4:4 and 5:3 compared to chickpea + linseed intercropping. Among all intercropping systems, chickpea + fenugreek (6:2) closely followed by chickpea + linseed (6:2) recorded significantly higher (34.6) IAI. The values of IAI followed the same trend with AYL values and concluded that all the intercropping showed intercropping advantage, of them, chickpea + fennel (4:2) had more IAI over remaining. Singh *et al.* (2021) reported that positive values of Monetary advantage index (MAI) of intercropping systems showed a definite yield advantage in chickpea based intercropping with linseed and Indian mustard compared to sole crop.

Relative economic efficiency and income equivalent ratio

Table 3 shown that intercropping had considerable impact on REE and IER. Chickpea + fenugreek recorded higher values of REE and IER than chickpea + linseed/ raya at all row combinations tested. Among all intercropping systems, chickpea + fenugreek (6:2) closely followed by chickpea + fenugreek (2:6) and chickpea + fenugreek (5:3) recorded significantly higher REE (0.47) and IER (1.47). Poddar *et al.* (2017) reported that intercropping of chickpea and fennel (4:2) recorded higher income equivalent ratio (2.03), thus proved most economical among the all the intercropping systems.

Economics

Cost of cultivation (Total and Variable) for chickpea + fenugreek intercropping was less than sole chickpea crop, while intercropping of linseed and raya raised the cost compared to sole chickpea. Intercropping of fenugreek in chickpea recorded higher net return, while chickpea + linseed/raya obtained lower net return compared to sole chickpea crop. Among all intercropping treatments, chickpea + fenugreek (6:2) closely followed by chickpea + fenugreek (2:6) recorded significantly higher net return (Rs. 96,170/ha) which was 12.7 percent higher over sole chickpea crop. Chickpea + fenugreek (2:6) closely followed by chickpea + fenugreek (6:2) recorded significantly higher BCR (3.79), VCR (2.79) and per day return (Rs. 641.9/ha/day), which were 8.91, 8.91 and 9.0 per cent higher over sole chickpea crop (Table 3). A similar economic advantage under different chickpea-based intercropping systems over sole chickpea was also reported by Singh *et al.* (2019) and Das *et al.* (2017).

CONCLUSION

The study came to the conclusion that intercropping of chickpea and fenugreek in varied row ratios (4:4, 5:3, 6:2, 3:5 and 2:6) was determined to be the most productive and cost-effective. Considering all intercropping indices, chickpea + fenugreek intercropping with a row ratio of 6:2 closely followed by chickpea + linseed (6:2) were found to be the most economical and suitable having higher LER (1.20), CEY (2396 kg/ha), LUE (119.3), ATER (1.18), A (0.53), RCC (4.18), MAI (18838), SPI (2208), IAI (34.6), Net Return (Rs. 96,170/ha), BCR (3.79), hence proved a most economical and suitable intercropping system for chickpea crop.

Conflict of interest

All authors declared that there is no conflict of interest.

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