Legume Research, 39 (1) 2016: 79-85
Print ISSN:0250-5371 / Online ISSN:0976-0571

AGRICULTURAL RESEARCH COMMUNICATION CENTRE
www.arccjournals.com/www.legumeresearch.in

Crop energy balance study of cotton-chickpea cropping sequence under organic and inorganic fertilizer sources in western Maharashtra

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Received: 09-07-2013 Accepted: 09-10-2013 DOI: 10.18805/lr.v39i1.8867

ABSTRACT

This study was conducted during the year 2006-07 and 2007-08 to determine how energy balances of crop production are affected by cotton-chickpea cropping sequence and different sources of organic and inorganic fertilizer under the semi-arid conditions of western Maharashtra. The energy input and output, energy balance per unit input ratio and the energy output/ input ratio were varied significantly individually to cotton and chickpea during both the years. However on pooled mean basis to cotton-chickpea cropping sequence, the energy input, output and energy balance were significantly higher by application of (RDF) Recommended Dose of Fertilizer according to Soil Test Crop Response (STCR) equation to cotton and 100% RDF to chickpea. Significantly higher energy balance per unit input and energy output per input ratio (6.46 MJ/ ha and 7.46) were recorded by 100% RDF + 10 FYM/ha to cotton and it was 5.72 MJ/ha and 6.72 by 100% RDF to chickpea. Application of RDF according to STCR equation (₹ 64960 and 3.07) to cotton and 100% RDF (₹ 46744 and 2.23) application to chickpea registered higher net monetary returns and benefit cost ratio respectively.

Key words: Chickpea, Cotton, Cropping sequence, Energy analysis, Inorganic fertilizer, Organic manure.

INTRODUCTION

Green revolution made India as a self sufficient country from food grains point of view but at the cost of indiscriminate use of chemical fertilizers, pesticide etc. and non renewable energy sources for tillage practices. Day by day the external inputs are increasing and productivity of crops is decreasing as soil health is deteriorating and high use of fossil fuel after high mechanization era. This is because of short term goals of production and productivity of crops and no plans for sustainable crop production.

After oil shocks during 1970s the whole world became cautious for energy and even recently one barrel crude oils price is more than $ 100/- and day by day the costs of other agricultural inputs are also rising, therefore energy analysis is becoming as an import indicator of farming system sustainability. To achieve the goals, solutions such as developing integrated nutrient management, diversified cropping sequences, conservation agriculture etc. have been proposed (Moreno *et al*. 2011). Energy inputs and outputs are important factors affecting the energy efficiency and environmental impact of crop production. (Rathke *et al.,* 2007). The efficiency of energy use can be increased by reducing inputs such as fertilizer, tillage operations and addition of legumes in cropping system or by increasing outputs such as crop yields (Swanton *et al.,* 2003).

Cotton is an important commercial crop of India, grown by four million farmers in an area of 7.4 million hectares. India occupies the foremost position in acreage, which is almost 25% of the global cotton area (FAO 2006). Cotton lint and seed are rich in high energy, also stalk and straw of the cotton offers great potential for biomass energy. Chickpea is the largest produced food legume in South Asia. Among the pulses chickpea occupies 30 per cent of area with 38 per cent of annual production in India and legume chickpea is purely a source of biomolecule protein which is also a source of high energy. During recent decades, biomass use for energy production has been proposed more and more as a substitute for fossil fuels. Biomass can offer an immediate solution in the reduction of CO_2 in the atmosphere.

Cotton and chickpea both are the crops of semi arid conditions and thrive well in high temperature, dry atmosphere with low availability of water. The aim of present work was to assess the effects of organic and inorganic fertilizers in cotton-chickpea cropping sequence on energy

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balance of crop production for two seasons for profitable production for the farmer with a minimal energy and environmental damage over time.

MATERIALS AND METHODS

The field experiment was conducted on same location during 2006-07 and 2007-08 at the postgraduate research farm of Department of Agronomy, MPKV, Rahuri, Dist. Ahmednagar (MS), India to find the effect of different organic and inorganic sources alone or in combination with each other on energy studies in hybrid cotton-chickpea cropping sequence under western Maharashtra condition in Mula river command area. The soil of the experimental field was medium black and fairly drained. The textural class was clayey. A dominant type of clay mineral was montmorillonite and grouped under order vertisol. The chemical composition indicated that the soil was low in available nitrogen (163.33 kg/ha), medium in organic carbon (0.52 %), low in available phosphorus (13.46 kg/ha) and very high in available potassium (467.33 kg/ha). The soil was alkaline in reaction (8.01).

The experiment was laid out in two design, randomized block design for cotton and split plot design for chickpea with three replications. The main plot comprising of seven treatments *viz*. 10 t farm yard manure (FYM)/ha + recommended dose of fertilizer (RDF) as 100:50:50 kg NPK /ha, 75 % RDF + 25 % recommended dose of nitrogen (RDN) through vermicompost, 50 % RDF + 50% RDN through vermicompost, 25 % RDF + 75 % RDN through vermicompost, 100 % RDN through vermicompost, RDF according to soil test crop response (STCR) equation and control were applied to hybrid cotton *cv. Phule-492* during summer season and the sub plot treatments comprising of four levels *viz.* control, 50 % RDF, 75% RDF and 100% RDF were applied @ 25:50:00 kg NPK/ha to chickpea *cv. Digvijay* during *rabi* season. Application of FYM and vermicompost was after laboratory to each particular treatment. The fertilizers were applied to the treatment RDF according to STCR equation as per the targeted yield equations developed by Soil Test Crop Response (STCR) Project, MPKV, Rahuri for summer cotton. Before planting of summer cotton, the soil was analyzed for available NPK (kg/ha) and analyzed values were put in following targeted yield equation of summer cotton. The targeted yield for summer cotton was 25 q/ha for both the seasons and the calculated fertilizer dose was 201.25:132.52:130.17 and 238.42:130.12:154.44 kg/ha NPK during first and second year respectively.

Targeted yield equation (STCR)

$F\ N = (13.1 \times T) - (0.75 \times SN)$

$F\ P_2O_5 = (6.83 \times T) - (2.84 \times SP)$

$F\ K_2O = (8.75 \times T) - (0.18 \times SK)$

Where,

FN = Nitrogen (kg/ha) to be applied from fertilizer

FP_2O_5 = Phosphorus (kg/ha) to be applied from fertilizer

FK_2O = Potash (kg/ha) to be applied from fertilizer

T = Targeted yield (q/ha)

SN = Available nitrogen (kg/ha) from the soil

SP = Available phosphorus (kg/ha) from the soil

SK = Available potassium (kg/ha) from the soil

Seed treatment of *Azotobacter* and PSB given to all treatments. ½ dose of N and entire P_2O_5 and K_2O was applied at the time of sowing, ¼ N at 30 days after sowing and ¼ N at 60 days after sowing was applied by ring placement method. The spacing for cotton was 90 cm x 90 cm and that of chickpea crop was 45 cm x 10 cm. The total inorganic fertilizer application to chickpea was done at the time of sowing itself. The energy balance were determined as reported by Verma *et al.* (1994). The energy balance variables considered during the study were, net energy produce (energy output minus energy input), energy balance per unit input ratio and the energy output/input ratio. Energy studies were carried out for cotton and chickpea individually and for cotton chickpea cropping sequence as a whole at the end of two seasons. This requires the identification of the inputs and the outputs involved and their conversion to energy values after harvesting cotton and chickpea treatment wise by means of corresponding energy coefficients or equivalents (Table 1).

The calculation of energy inputs was based on estimating the total direct (fuel) and indirect energy factors (energy used in producing machines, fertilizers, seeds *etc.*) involved but not including those unrelated to production (energy used in processing, storage, transport *etc.*).The energy output for both crops was considered as the caloriefic value of the harvested main product. This was calculated based on the total yield (kg/ha) and its corresponding energy coefficient (Table 1.), estimated at 25.00 and 17.40 MJ/kg for cotton seed and stalk respectively and 14.70 and 12.50 MJ/kg for chickpea seed and bhusa respectively. Crop residues were also considered in the energy balance since they are also bearing economic and caloriefic values. Data corresponding to both the seasons was analysed using the randomised block and split plot procedure for cotton and chickpea respectively. Energy inputs were not analysed statistically since they cannot be considered random variables to be constant for each sequence in every season.

RESULTS AND DISCUSSION

Energy analysis of cotton: In cotton energy input was more influenced by addition of organic and inorganic sources of fertilizers in different treatments. Total energy inputs in cotton

TABLE 1: Details of energy values of input and output used for energy studies of summer cotton and *rabi* chickpea.

Input/output items	Energy value (MJ)
Inputs	
Self propelled machine (Tractor) (MJ/ha)	68.40
Human labour (MJ/ha)	1.96
Fuel (Diesel) (MJ/L)	56.31
Electricity (KW/hr)	11.93
Chemical fertilizers	
Nitrogen (MJ/kg)	60.00
Phosphorus (MJ/kg)	11.10
Potassium (MJ/kg)	6.70
Biofertilizers	
Azotobacter (MJ/kg)	10.00
Rhizobium (MJ/kg)	10.00
PSB (MJ/kg)	10.00
Organic manures	
Farm yard manure (MJ/kg)	0.30
Vermicompost (MJ/kg)	0.30
Seed	
Cotton (MJ/ kg)	15.20
Chickpea (MJ/kg)	15.20
Chemical	
Endosulphan (35 EC) (MJ/L)	120.00
Deltamethrin (2.8 EC) (MJ/L)	120.00
Chlorophyriphos (MJ/kg)	120.00
Outputs	
Main product	
Cotton seed (MJ/kg)	25.00
Chickpea grain (MJ/kg)	14.70
By products	
Cotton stalk (MJ/kg)	17.40
Chickpea bhusa (MJ/kg)	12.50

(Table 2) were about 2.5 and 2 times higher in treatment RDF according to STCR equation (25257 and 26147MJ/ha during 1st and 2nd year respectively) and in treatment 10 t FYM/ha+ RDF (20729 and 20079 MJ/ha during 1st and 2nd year respectively) respectively during both the years as compared to control which has recorded lowest energy inputs. Treatment 100% RDN through vermicompost was totally a organic nitrogen treatment, which costs lowest energy inputs among the other treatments where organic and inorganic sources of fertilizers were applied. Energy output increased significantly in the order of treatment RDF according to STCR equation (204250 and 212750MJ/ha during 1st and 2nd year respectively) followed by 10 t FYM/ha+ RDF (175650 and 175350 MJ/ha during 1st and 2nd year). Significantly higher energy output in RDF according to STCR equation was due to higher yield and significantly lowest energy out put was recorded in control due to lowest yield of cotton. Thus energy consumption under normal nutrient application practice i.e. GRDF is greater and fertilizer application by STCR equation and showing highest energy demand which is in agreement with Rathke *et al.* (2007). Energy output was recorded lowest in the organic nitrogen source treatment, 100% RDN through vermicompost among other treatments where organic and/ or inorganic sources of fertilizers were applied due to lower crop yields. Organic nitrogen source treatment resulted in reduced yields, but the increase of yields with the use of agrochemicals for other treatments is at expense of an increase in the energetic costs and consequently in the CO_2 emission and environmental impact. The results are in agreement with those reported by Moreno *et al.* (2011).Significantly highest energy balance was recorded in treatment RDF according to STCR equation (178993 and 186603 MJ/ha during 1st and 2nd year respectively) followed by 10 t FYM/ha + RDF (154921 and 178271 MJ/ha during 1st and 2nd year respectively), which was 2.12 and 2.16 times higher over control respectively. Significantly higher energy balance per unit input (7.92 and 8.94 MJ/ha) and energy output per input ratio (8.92 and 8.94) in cotton was recorded in 75 % RDF + 25 % RDN through vermicompost followed by the treatment 50 % RDF + 50 % RDN through vermicompost. Lowest energy balance per unit input (7.14MJ/ha) and energy output per input ratio (8.14) in cotton was recorded in in treatment RDF according to STCR equation during second year which has received highest fertilizer dose ultimately due to more energy inputs. Sharma *et al.*(2011) observed that conservation agriculture and use of integrated nutrient management is more sustainable than sole going for chemical fertilizer and the same trend can be seen here.

Energy analysis of chickpea: Maximum total energy input (Table 3) in chickpea was estimated in fertilizer level 100% RDF (16072 and 16256 MJ/ha during 1st and 2nd year respectively). Total energy output in chickpea was about 1.77 and 1.72 times higher in treatment 10 t FYM /ha+ RDF and treatment 100% RDN through vermicompost applied over control. Treatment 10 t FYM /ha+ RDF recorded significantly higher total energy output(72196 and 84463 MJ/ha) and it was found at par with application of 100% RDN through vermicompost (69583 and 82472 MJ/ha) during both the years of experimentation in the main plots. This could be attributed to higher biomass production which is directly proportional to energy production where there was integration of inorganic fertilizers and organic manures like FYM and vermicompost applied to preceding crop summer cotton followed by chickpea. The results are in agreement with those reported by Swaminathan *et al.* (1994). In sub plots 100% RDF (71099 and 81537 MJ/ha) recorded significantly higher energy output followed by 75% RDF (68233 and 68351 MJ/ha) during both the years. Total energy output was 1.58 and 1.51 times higher in treatment 100% RDF and 75% RDF respectively in sub plots over control. Significantly higher

TABLE 2: Energy input, energy output, energy balance, energy balance per unit input and energy output/input ratio of cotton as influenced by different treatments.

Treatments	Energy input (MJ/ha)		Energy output (MJ/ha)		Energy balance (MJ/ha)		Energy balance per unit input (MJ/ha)		Energy output per input ratio	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Main plot treatments										
GRDF (10 t FYM/ha + RDF)	20729	20079	175650	198350	154921	178271	7.47	8.88	8.47	9.88
75 % RDF + 25 % RDN through VC	17256	16467	153950	163675	136694	147208	7.92	8.94	8.92	9.94
50 % RDF + 50 % RDN through VC	16074	15301	139175	151200	123101	135899	7.66	8.88	8.66	9.88
25 % RDF + 75 % RDN through VC	15061	14134	114325	134750	99264	120616	6.59	8.53	7.59	9.53
100 % RDN through VC	13964	12967	105275	120700	91311	107733	6.54	8.31	7.54	9.31
RDF according to STCR equation	25257	26147	204250	212750	178993	186603	7.09	7.14	8.09	8.14
Control	10839	10189	79550	96550	68711	86361	6.34	8.48	7.34	9.48
SE(m)	--	--	8990	8127	8990	8127	0.56	0.58	0.56	0.58
CD at 5 % level	--	--	27661	25007	27661	25007	1.64	1.72	1.64	1.72

TABLE 3: Energy input, energy output, energy balance, energy balance per unit input and energy output/input ratio of chickpea as influenced by different treatment.

Treatments	Energy input (MJ/ha)		Energy output (MJ/ha)		Energy balance (MJ/ha)		Energy balance per unit input (MJ/ha)		Energy output per input ratio	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Main plot treatments										
GRDF (10 t FYM/ha + RDF)	15176	15336	72196	84463	57184	69127	3.76	4.51	4.75	5.51
75 % RDF + 25 % RDN through VC	15176	15336	51449	65337	36274	50002	2.39	3.26	3.39	4.26
50 % RDF + 50 % RDN through VC	15176	15336	61729	72812	46553	57476	3.07	3.75	4.07	4.75
25 % RDF + 75 % RDN through VC	15176	15336	63535	74380	48359	59044	3.19	3.85	4.19	4.85
100 % RDN through VC	15176	15336	69583	82472	54408	67136	3.59	4.38	4.59	5.38
RDF according to STCR equation	15176	15336	61763	72582	46588	57247	3.07	3.73	4.07	4.73
Control	15176	15336	37794	51627	22619	36291	1.49	2.37	2.49	3.37
SE(m)	--	--	1581	2088	1581	2088	0.10	0.13	0.10	0.13
CD at 5 % level	--	--	4376	6434	4376	6434	0.28	0.41	0.28	0.41
Sub plot treatments										
Control	14017	14201	40814	57527	26797	43327	1.91	3.05	2.91	4.05
50 % RDF	15045	15228	58739	70397	43694	55169	2.91	3.62	3.91	4.62
75 % RDF	15474	15657	68233	78351	52759	62694	3.41	4.00	4.41	5.00
100 % RDF	16072	16256	71099	81537	55027	65281	3.42	4.02	4.42	5.02
SE(m)	--	--	1883	1900	1883	1900	0.12	0.12	0.12	0.12
CD at 5 % level	--	--	5211	5424	5211	5424	0.34	0.35	0.34	0.35

energy balance was recorded by application of 10 t FYM / ha + RDF followed by 100% RDN through vermicompost to the tune of 69127 and 67136 MJ/ha respectively during second year. More energy balance recorded in succeding crop chickpea due to application of INMS and organic treatment to the preceding crop cotton. Significantly higher energy balance was recorded by 100% RDF (55027 and 65281 MJ/ha), which was 207% higher during 1st year and 150% during 2nd year over control in sub plots. This was due to more biomass production because of more fertilizer supply to higher fertilizer levels. Significantly higher energy balance per unit input (3.76 and 4.51 MJ/ha) and energy output per input ratio (4.75 and 5.51) was observed by application of 10 t FYM/ ha + RDF followed by the organic treatment 100% RDN through vermicompost during both the years, hence organic nitrogen source treatment showing better results in the succeeding crops due to their residual effect as far as energy parameters are concerned and also the crop rotation involving a leguminous crop provided extra support, these results are in agreement with Hernanz *et al.* (1995) however in sub plots significantly higher energy balance per unit input (3.42 and 4.02 MJ/ha) and energy per input ratio (4.42 and 5.02) was observed by application of 100% RDF which was found at par with 75% RDF during both the years of experiment.

Energy analysis of cotton-chickpea cropping sequence: Pooled mean of crop sequence (Table 4) of both the years shows, the total energy inputs were 1.26 and 1.24 times higher due to application of RDF according to STCR equation (35972 MJ/ha) and 10 t FYM/ha + RDF (35577 MJ/ha) over control (28617 MJ/ha). Total energy input in RDF according to STCR equation during both the years made highest contribution the due to high quantity fertilizer application, same trend was found due to high fertilizer application in chickpea where highest pooled energy input recorded in 100% RDF (32912 MJ/ha). Nitrogen fertilizer and organic source FYM accounted for single largest share of energy input followed by diesel and human labour. The energy input through seeds, plant protection chemicals, fertilizer potash and phosphorus was of lower magnitude. Similar findings were observed by Parihar *et al.* (1999). Application of RDF according to STCR equation to cotton recorded significantly higher total energy output and which was at par with 10 t FYM/ha + RDF during both the years but significantly superior total energy output was registered by application of RDF according to STCR equation in pooled analysis (275673 MJ/ha). Application of 100% RDF to chickpea recorded significantly higher total energy output and which was at par with 75% RDF during both the years however in pooled analysis total energy output was significantly superior by application of 100% RDF (222757 MJ/ha) to chickpea. As determined by pooled energy balance of the cropping sequence, RDF according to STCR equation appeared to be about 2.19 times more energetically efficient than 10 t FYM/ha + RDF (2.14) over control. RDF according to STCR equation added significantly higher energy balance followed by 10 t FYM/ha + RDF during both the years and on pooled mean basis (234715 MJ/ha). 100% RDF recorded significantly higher energy balance during both the years and on polled mean basis (189846 MJ/ha) and which was at par with 75% RDF application to chickpea. In the two years sequence inclusion of a leguminous crop chikpea increased the total energy output under all treatments, in agreement with Rathke *et al.*(2007). As determined by the energy balance per unit input and energy output per input ratio of cotton-chickpea cropping sequence, it appears that application of 10 t FYM/ha + RDF (6.46 MJ/ha and 7.46) to cotton was most energetically efficient followed by 50% RDF+ 50% RDN through vermicompost (5.86 MJ/ha and 6.86), 75% RDF + 25% RDN through vermicompost (5.77 MJ/ha and 6.77) and application of RDF according to STCR equation (5.73 MJ/ha and 6.73). These results are in agreement with Gawai (2003). In two year sequence, application of RDF according to STCR equation recorded highest energy output but it also consumed the highest amount of energy resulting in lower energy balance per unit input and energy output per input ratio. Among the subplots 75% RDF (5.75 MJ/ha and 6.75) was found most energetically efficient instead of 100% RDF (5.72 MJ/ha and 6.72) on pooled mean basis respectively for energy balance per unit input and energy output per input ratio.

Economics of cotton-chickpea cropping sequence: Pooled mean of economics of cotton-chickpea sequence (Table 5) during both the years shows maximum cost of cultivation in cotton is estimated in treatment 100% RDN through vermicompost (₹49323) followed by 25 % RDF + 75 % RDN through vermicompost (₹44375), however in chickpea it was highest in 100% RDF (₹ 38127). The difference in cost of cultivation is due to difference in the levels of fertilizer and

TABLE 4: Energy input, energy output, energy balance, energy balance per unit input and energy output/input ratio as influenced by different treatments in cotton-chickpea sequence.

Treatments	Energy input (MJ/ha)			Energy output (MJ/ha)			Energy balance (MJ/ha)			Energy balance per unit input (MJ/ha)			Energy output per input ratio		
	2006-07	2007-08	Pooled mean	2006-07	2007-08	Pooled mean	2006-07	2007-08	Pooled mean	2006-07	2007-08	Pooled mean	2006-07	2007-08	Pooled mean
Main plot treatments															
GRDF (10 t FYM/ha + RDF)	35740	35414	35577	247846	282813	265329	212106	247398	229752	5.93	6.99	6.46	6.93	7.99	7.46
75 % RDF + 25 % RDN through VC	32432	34512	33472	205399	229012	217206	172967	197209	185088	5.33	6.20	5.77	6.33	7.20	6.77
50 % RDF + 50 % RDN through VC	31249	33609	32429	200904	224012	212458	169654	193376	181515	5.42	6.30	5.86	6.42	7.30	6.86
25 % RDF + 75 % RDN through VC	30237	32706	31472	177860	209130	193495	147623	179661	163642	4.88	6.10	5.49	5.88	7.10	6.49
100 % RDN through VC	29139	31803	30471	174858	203172	189015	145719	174870	160295	5.00	6.18	5.59	6.00	7.18	6.59
RDF according to STCR equation	40433	31511	35972	266013	285332	275673	225580	243850	234715	5.58	5.88	5.73	6.58	6.88	6.73
Control	26014	31219	28617	117344	148177	132761	91330	122653	106992	3.50	4.80	4.15	4.50	5.80	5.15
SE(m)	--	--	--	8759	8500	2760	8759	8500	8171	0.28	0.26	0.26	0.28	0.27	0.26
CD at 5 % level	--	--	--	24243	23525	7998	24242	23525	25174	0.77	0.80	0.80	0.77	0.85	0.80
Sub plot treatments															
Control	31043	30670	30857	179696	211524	195610	148653	180854	164754	4.70	5.84	5.27	5.70	6.84	6.27
50 % RDF	32071	31697	31884	197621	224394	211008	165551	192697	179124	5.09	6.04	5.57	6.09	7.04	6.56
75 % RDF	32499	32126	32313	207115	232347	219731	174616	200221	187419	5.30	6.20	5.75	6.30	7.20	6.75
100 % RDF	33098	32725	32912	209981	235534	222757	176883	202809	189846	5.27	6.17	5.72	6.27	7.17	6.72
SE(m)	--	--	--	1883	1900	634	1883	1900	1618	0.06	0.05	0.05	0.06	0.06	0.05
CD at 5 % level	--	--	--	5211	5259	1837	5211	5259	4620	0.16	0.15	0.15	0.16	0.17	0.15

TABLE 5: Economics of cotton-chickpea cropping sequence as influenced by different treatments (Pooled mean).

Treatments	Cost of cultivation (₹/ha)	Gross monetary returns (₹/ha)	Net monetary returns (₹/ha)	Benefit : Cost ratio
Main plot treatments				
GRDF (10 t FYM/ha + RDF)	38605	96474	57870	2.50
75 % RDF + 25 % RDN through VC	34236	77613	43377	2.27
50 % RDF + 50 % RDN through VC	39275	78707	39433	2.00
25 % RDF + 75 % RDN through VC	44375	74914	30539	1.69
100 % RDN through VC	49323	75212	25889	1.52
RDF according to STCR equation	31400	96360	64960	3.07
Control	26115	50922	24807	1.95
SE(m)	—	718	579	—
CD at 5 % level	—	2082	1679	—
Sub plot treatments				
Control	36966	68688	31722	1.86
50 % RDF	37547	77765	40218	2.07
75 % RDF	37834	83077	45243	2.20
100 % RDF	38127	84871	46744	2.23
SE(m)	—	264	267	—
CD at 5 % level	—	767	775	—

manures levels applied and their respective cost. Application of 10t FYM/ha + RDF (₹96474) to cotton recorded significantly superior gross monetary returns and it was found at par with RDF according to STCR equation (₹ 96360), however rest of the treatments were at par with each other. Among chickpea levels 100% RDF (₹ 84871) application recorded significantly superior gross monetary returns. Application of RDF according to STCR equation (₹ 64960) recorded significantly superior net monetary returns followed by application of 10t FYM/ha + RDF (₹ 57870) to cotton, however it was also significantly superior in chickpea by application of 100% RDF (₹46744). In cotton application of RDF according to STCR equation (3.07) recorded highest benefit cost ratio followed by 10t FYM/ha + RDF (2.50) and lowest benefit cost ratio was recorded in control (1.95), however among application of 100% RDF (2.23) to chickpea recorded highest benefit cost ratio followed by 75% RDF (2.20). There results are in agreement with Gawai (2003).

It is obvious from the present study that application of RDF according to STCR equation showed highest energy input, energy output and energy balance but highest energy balance per unit input and energy output per input ratio recorded was recorded by application of 10 t FYM/ha + RDF followed by other integrated nutrient management treatments to cotton and in chickpea also application of 75% RDF proved more energy efficient over 100% RDF. It means chcmical fertilizer was most important energy input source but its efficiency with other energy parameters was low, due to which use of chemical fertilizer should be reduced. However organic nitrogen source and other integrated nutrient management treatments shown significant nutrient residual effect to succeeding crop and which were suited better to energy efficiency and environmental conditions. Crop rotation especially with legume crop was more sustainable and increased the energy efficiency of whole cotton-chickpea cropping sequence. But from economic point of view application of RDF according to STCR equation to cotton and 100% RDF to chickpea shown its superiority in the parameters like net monetary returns and benefit cost ratio.

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