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Research Paper

Effects of resource conservation technologies on productivity, nutrient acquisition, employment generation and energetics of maize (*Zea mays*)-based cropping systems in North-Western Himalayan region

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ABSTRACT

A field experiment was conducted during the rainy season (*kharif*) 2012–13 and winter season (*rabi*) 2013–14 at Palampur, Himachal Pradesh, to evaluate the effect of resource conservation technologies (RCTs) on productivity, nutrient acquisition and energetics of maize (*Zea mays* L.)-based cropping system. The experiment was conducted in split-plot design, replicated thrice with 2 tillage methods, viz. zero tillage (ZT) and conventional tillage (CT); and 3 cropping systems, viz. maize (*Zea mays* L.)–wheat (*Triticum aestivum* L.) (M–W), baby corn (*Zea mays*) + Frenchbean (*Phaseolus vulgaris* L.)–pea (*Pisum sativum* var. *hortense*.)–summer squash (*Cucurbita pepo* L.) (BC+FB–P–SS) and maize + soybean [*Glycine max* (L.) Merr.]–*gobhi sarson* (*Brassica napus* L.) + *toria* (*Brassica campestris* var. black toria) (M+S–GS+T) in main plot; and 2 mulch levels, viz. no mulch (NM) and crop-residue mulch (CRM); and 2 fertilizer levels, viz. recommended dose of fertilizers (RDF) and 75% of RDF + 25% N through FYM (INM) in subplot. The results revealed that CT resulted in significantly higher maize grain-equivalent yield (MGEY 11.4%), biological yield (12.3%), system output energy (7.9%), net energy (13.4%), energy productivity (12.8%), energy output efficiency (7.9%) and energy intensity in economic terms (4.6%) than ZT. Among the cropping systems, BC+FB–P–SS showed higher MGEY (190.8%), biological yield (97.3%), employment generation (55.9%) and energy productivity (138.0%) and also consumed higher energy input (29.3%) than the traditional M–W cropping system. The N, P and K uptake was the highest in M+S–GS+T. Application of crop-residue mulch and INM resulted in significantly higher MGEY, biological yield and system energy input. Thus conventional tillage proved best in terms of MGEY, biological yield and energy indices by providing more yield than zero tillage. Further, diversifying the existing cropping system with vegetable-based cropping system can be more profitable to the hill farmers and can provide more regular employment opportunities.

Key words: Biological yield, Energy input, Energy productivity, Maize grain-equivalent yield, Zero tillage

Natural resource degradation due to repeated tillage operations on slopy land along with residue burning/ removal for domestic fuel and livestock fodder are the major concerns for sustainability of agriculture in the mountainous region (Ghosh *et al.,* 2010). Intensive tillage operations on sloping lands results in severe soil erosion and reduces soil aggregation and soil organic carbon content through accelerated oxidation. Hence adoption of zero tillage, residue retention/ incorporation and crop diversification may be a viable alternative for better resource conservation and to overcome the imposed constraints of the climate change and high input costs (Aune, 2009). Crop diversification and intensification which include legumes, oilseeds, vegetables, high-value crops and employment-generating crops can improve the economic condition of small and marginal farmers owing to higher price and higher volume of their main and byproducts (Sharma *et al.,* 2004). The imbalance nutrient application and higher dependence on inorganic fertilizers alone under increased cropping intensity are the major causes of reduced soil productivity. So, integration of organics with inorganic sources of nutrients is essential. It ensures regulated supply of nutrients, resulting in increased crop yield and nutrient-use efficiency, by increasing SOC, availability of nutrients and soil microbial properties (Melero *et al.,* 2007).

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Modern agriculture system which involves high-energy input such as mechanical (farm machines and human labour), fertilizers, pesticides, diesel and electricity (Devsenapathy *et al.,* 2009) results in higher cost of production and reduced input-use efficiency. In the changing climatic scenario, sustainability of any cropping system lie on its energy-use pattern. Further, effective energy use in agriculture is one of the conditions for sustainable agricultural production and to achieve higher productivity and profitability in terms of financial savings, fossil fuel preservation and air pollution reduction (Uhlin, 1998). Therefore, energy analysis is the most common approach to examine energy input-output relationship or energy-use efficiency of the production system. Energy analysis provides an accurate overall evaluation of the non-renewable energy consumption linked to agriculture for determining elasticity of inputs on yield and production. Zero tillage (ZT) as a resource conservation technology has the potential to reduce cultivation cost as major portion of energy (25–30%) is utilized for field preparation and crop establishment, besides environmental benefits as compared to conventional tillage (Filipovic *et al.,* 2006). Hence there is a dire need to think for more productive, efficient and remunerative cropping systems with suitable tillage practices for sustainable use of natural resources. Keeping these aspects in view, the study under reference was undertaken.

MATERIALS AND METHODS

A field experiment was carried out at the research farm of the Department of Agronomy, Chaudhary Sarwan Kumar, Himachal Pradesh Krishivishvavidyalaya, Palampur (32°6' N and 76°3' E, 1,290 m above mean sea level), Himachal Pradesh, during *kharif* 2012–*rabi* 2013–14. The soil was silty clay loam, having 418.5 kg/ha alkaline permanganate-oxidized N, 40.1 kg/ha available P, 198.7 kg/ha 1 N ammonium acetate-exchangeable K and 1.12% organic carbon. The *p*H of soil was 5.4. The experiment was laid out in split-plot design with 3 replications. The treatments in main plot were the combinations of 2 tillage methods, viz. zero tillage (ZT) and conventional tillage (CT); 3 cropping systems, viz. maize–wheat (M-W), baby corn + frenchbean–pea–summer squash (BC + FB–P–SS) and maize + soybean–*gobhi sarson* + *toria* (M + S–GS + T). The treatments in subplot were the combinations of 2 levels of mulch, viz. no mulch (NM) and crop-residue mulch (CRM), and 2 fertilizer levels, viz. recommended dose of fertilizers (RDF) and 75% of RDF + 25% N through FYM (INM). In minimum/ zero tillage (ZT) treatment, seeds were sown by opening the furrows after hand plough without any preparatory tillage operations. However, the summer squash seedlings were transplanted after digging a pit/ hole of suitable size without tilling the field. In conventional tillage (CT) treatment, sowing was done following 2 tillage operations (up to 15 cm soil depth) made by power tiller. After the complete emergence of crop, mulching was done as per the treatment combination. Crop residue of preceding crops (wheat straw at the start of the experiment) was used on succeeding crops @ 5 tonnes/ha. All the crops in different cropping systems were raised in accordance with recommended package of practices for the state (Table 1). The intercrops were grown in paired-row system. The weight of grain yield of maize, soybean, wheat, *gobhi sarson* and *toria* from net plots in each treatment after threshing was weighed and weight was expressed in tonne/ha. In case of baby corn, frenchbean, pea and summer squash the weight of green cobs/ pods/ fruits recorded from each plot over different picking was added and expressed as tonne/ha. For comparison between crop sequences, the yields of crops were converted into maize–grain-equivalent yield (MGEY) on prevalent market price basis (Verma and Modgal, 1983) and expressed as tonne/ha. Chemical analyses of plants were done by following the standard procedures. The total number of labour involved for various agronomic operations were noted treatment area-wise and involved in each plot. Based on this, total requirement of labour/ha was worked out.

To calculate energy inputs, the energy equivalents (Singh and Mittal, 1992) pertaining to labour, seed, chemical fertilizer, herbicides and pesticides used in the crop sequences were taken into consideration. The energy output (MJ/ha) of each crop was obtained by multiplying the energy equivalents with grain and straw separately to get the total energy output. Energy-use efficiency (EUE), specific energy (SE) and energy productivity were worked out as per Demircan *et al.* (2006). Net energy, energy-output efficiency, energy intensity in economic terms and energy intensity in physical terms were calculated as:

Net energy= Energy output (MJ/ha) – Energy input (MJ/ha)

$$\text{Energy output efficiency} = \frac{\text{Energy output (MJ/ha)}}{\text{Duration of the system (days)}}$$

$$\text{Energy intensity in economic terms} = \frac{\text{Energy output (MJ/ha)}}{\text{Cost of cultivation (₹)}}$$

$$\text{Energy intensity in physical terms} = \frac{\text{Energy input (MJ/ha)}}{\text{Total output (grain + straw) (kg/ha)}}$$

The data were statistically analysed using the F-test as per the procedure given by Gomez and Gomez (1984). CD values at P=0.05 were used to determine the significance of difference between treatment means.

Table 1. Agronomic practices of individual crop followed during experimentation

Crop	Variety	Seed rate (kg/ha)	Spacing (cm × cm)	Fertilizers (N : P_2O_5 : K_2O kg/ha)	No. of irrigation 2012–13	No. of irrigation 2013–14	Date of sowing 2012–13	Date of sowing 2013–14	Date of harvesting 2012–13	Date of harvesting 2013–14	Crop duration 2012–13	Crop duration 2013–14	No. of intercultural operation 2012–13	No. of intercultural operation 2013–14
Rainy season														
Maize (sole)	'Early Composite' (2012) 'Kanchan' (2013)	20	60 × 20	120 : 60 : 40	3	–	10 June 2012	6 June 2013	26 September 2012	25 September 2013	108	111	–	2
Baby corn	'VL 78'	20	60 × 20	120 : 60 : 40	3	–	10 June 2012	18 June 2013	22 August 2012	06 September 2013	73	78	–	2
Frenchbean	'Laxmi'	30	60 × 20	25 : 25 : 25	3	–	10 June 2012	18 June 2013	13 August 2012	26 August 2013	64	69	–	2
Maize (intercrop)	'Early Composite' (2012) 'Kanchan' (2013)	20	60 × 20	120 : 60 : 40	3	–	10 June 2012	6 June 2013	26 September 2012	25 September 2013	108	111	–	2
Soybean	'Harit Soya'	50	60 × 20	15 : 20 : 20	4	–	10 June 2012	6 June 2013	22 October 2012	10 October 2013	138	126	–	2
Winter season														
Wheat	'HPW 155'	100	22.5	120 : 60 : 30	4	3	26 October 2012	18 October 2013	8 May 2013	22 May 2014	194	216	3	2
Pea	'Palam Samool' (2012-13) 'Palam Priya' (2013-14)	75	40 × 10	25 : 60 : 60	4	3	26 October 2012	16 October 2013	17 April 2013	11 April 14	199	177	3	2
Gobhi sarson	'HPN 1'	6	22.5	120 : 60 : 40	4	3	26 October 2012	16 October 2013	24 April 2013	24 April 2014	180	190	3	2
Toria	'T 9'	12	22.5	60 : 60 : 40	4	3	26 October 2012	16 October 2013	6 March 2013	20 February 2014	131	127	3	2
Summer season														
Summer squash	'Australian Green'	8	80 × 60	100 : 50 : 55	7	5	30 April 2013	11 April 2014	11 June 2013	9 June 14	48	59	5	1

RESULTS AND DISCUSSION

Maize grain-equivalent yield and biological yield

The maize grain-equivalent yield (MGEY) and biological yield recorded are presented in Table 2. Zero tillage resulted in comparable economic yield in the rainy and winter seasons except summer season. However, MGEY and biological yields were significantly higher under conventional tillage owing to higher production of individual crops because of better pulverization of soil which might have helped in better air exchange, high nutrient availability and less crop-weed competition over zero tillage. Higher soil compaction due to non-tilling operations under zero tillage resulted in poor germination and growth of crop which further resulted in lower biological yield and MGEY. Among the cropping systems, baby corn + frenchbean–pea–summer squash exhibited higher MGEY (190.8%) and biological yield (97.3%) over the traditional maize–wheat cropping sequence. Higher production and market value of vegetables like baby corn, frenchbean, pea and summer squash was the main reason of higher MGEY. Rana *et al.* (2011) also reported higher MGEY with vegetables involving cereal-based cropping system. Application of crop-residue mulch increased the MGEY and biological yield by 7.5 and 4.4%, respectively, over the yield obtained in plots without mulch. Improvement in moisture with reduced water evaporation losses and fluctuations in water availability, heat and air regime and weed suppression favoured the crop growth and hence higher yield (Kumar *et al.*, 2013). Applying 25% N of recommended dose of fertilizer through FYM also resulted in significantly higher MGEY and biological yield over pure inorganics. This might be owing to improvement in soil fertility with addition of organic manure.

Interaction effect

Interaction effect of tillage and mulch levels was found significant for MGEY (Table 3). Under zero tillage, crop-residue mulch resulted in higher MGEY than no mulch, while under conventional tillage no significant effect was found on MGEY. Under no-mulch condition, conventional tillage resulted in higher MGEY, while under crop-residue mulch, both were found at par. Overall conventional till-

Table 2. Effect of resource-conservation technologies on economic yield, maize grain-equivalent yield (MGEY), nitrogen, phosphorus and potassium uptake and employment generation (pooled data of 2 years)

Treatment	Economic yield (tonnes/ha)			MGEY (tonnes/ha)	Total biological yield (tonnes/ha)	Total N uptake (kg/ha)	Total P uptake (kg/ha)	Total K uptake (kg/ha)	Employment generation (days/ha/annum)
	Rainy season	Winter	Summer						
Tillage									
ZT	4.23	2.74	3.93	13.18	32.58	229.1	42.6	123.8	262
CT	4.20	2.86	5.33	14.66	36.58	237.5	44.1	131.4	236
SEm±	0.06	0.12	0.15	0.29	0.57	5.36	1.26	2.42	–
CD (P=0.05)	NS	NS	0.48	0.92	1.81	NS	NS	NS	–
Cropping systems									
M–W	3.91	3.62	-	8.04	26.41	240.8	38.3	115.3	202
BC + FB – P – SS	4.34	3.03	13.89	23.38	52.15	156.6	32.8	91.4	315
M + S – GS + T	4.39	1.75	-	10.34	25.18	302.5	59.1	176.0	231
SEm±	0.07	0.15	0.19	0.36	0.70	6.57	1.54	2.97	
CD (P=0.05)	0.23	0.48	0.59	1.13	2.22	20.70	4.85	9.35	–
Mulch									
NM	4.24	2.71	4.27	13.43	33.81	231.3	45.0	125.9	238
CRM	4.19	2.89	4.99	14.42	35.34	235.2	41.8	129.2	261
SEm±	0.05	0.04	0.9	0.12	0.24	2.24	1.32	1.33	–
CD (P=0.05)	NS	0.11	0.25	0.34	0.68	NS	NS	NS	–
Fertilizer									
RDF	4.10	2.75	4.55	13.63	33.77	229.2	44.0	124.7	244
INM	4.33	2.85	4.71	14.22	35.39	237.4	42.7	130.4	255
SEm±	0.05	0.04	0.9	0.12	0.24	2.24	1.32	1.33	–
CD (P=0.05)	0.15	0.11	NS	0.34	0.68	6.42	NS	3.81	–

ZT, Zero tillage; CT, conventional tillage; M–W, maize–wheat; BC + FB – P – SS, baby corn + frenchbean–pea–summer squash; M + S – GS + T, maize + soybean –*gobhi sarson* + *toria*; NM, no mulch; CRM, crop-residue mulch; RDF, recommended dose of fertilizer; INM, 75% RDF + 25% N through organic manure; NS, non-significant age with crop-residue mulch, being at par with conventional tillage with no mulch, and zero tillage with crop residue mulch resulted in significantly higher MGEY. Similarly, with respect to cropping system and mulching, baby corn + frenchbean–pea–summer squash with crop-residue mulch resulted in significantly highest MGEY as compared to the other treatment combination. This was followed by baby corn + frenchbean–pea–summer squash without mulch (Table 3). Maintaining residue on the soil surface has not always been shown to increase yields. According to Wicks *et al.* (1994), plant yield response to mulching was variable and depends on how long plant development was delayed due to lower soil temperatures and higher water conserved and how much water stress occurred and the amount and distribution of precipitation.

Nutrient acquisition

In spite of significantly lower MGEY, the zero tillage was comparable to the conventional tillage in influencing total system's nitrogen (N), phosphorus (P) and potassium (K) uptake (Table 2). Among the cropping systems, maize + soybean–*gobhi sarson* + *toria* resulted in significantly higher N, P and K uptake followed by maize–wheat and lowest in baby corn + frenchbean–pea–summer squash. Higher uptake in maize + soybean–*gobhi sarson* + *toria* crop sequence was owed to higher dry-matter production of crops in this cropping system, while higher MGEY and biological yield under baby corn + frenchbean–pea–summer squash did not result in higher nutrient uptake due to higher moisture content in vegetable crops and less dry-matter accumulation. However, mulch did not affect total system's N, P and K uptake significantly. In case of fertilizer, integrated nutrient management practice resulted in significantly higher uptake of N and K which may be ascribed to higher biomass production owing to higher nutrient uptake. Higher availability of nutrients owing to improved physiological and metabolic functions inside the plant might have been responsible for better expression of growth parameters, yield and nutrient uptake. The findings are in line with those of Kumar and Dhar (2010).

Employment generation

The data on employment generation in different treatments showed that among the tillage systems, zero tillage resulted in higher employment generation than the conventional tillage (Table 2). This might be due to higher labour requirement for scrapping of weeds for field preparation before sowing and higher weeds problem which required extra man power. Among the cropping system, the highest employment generation was noticed in baby corn + frenchbean–pea–summer squash, followed by maize + soybean–*gobhi sarson* + *toria* as compared to maize–wheat cropping system which may be ascribed to cultivation of vegetable crops involving intensive cultural operations starting from sowing to marketing. Further, vegetables and legumes can provide more regular employment opportunities than cereals in rural areas. Application of crop-residue mulch and FYM also required extra manpower as compared to no-mulch and recommended dose of fertilizer.

Economics

Due to sowing in the row zone only, zero tillage recorded lower cost of cultivation than conventional tillage (Fig. 1). But, lower cost of cultivation under zero tillage did not reflect in net returns and benefit: cost ratio which

Table 3. Interaction effect of tillage and mulch, and cropping systems and mulch on MGEY (tonnes/ha) (pooled data of 2 years)

Mulch	Tillage	
	T_1	T_2
M_1	12.43	14.42
M_2	13.94	14.91
	SEm±	CD (P=0.05)
Mulch levels at the same levels of tillage	0.17	0.48
Tillage at the same or different levels of mulch	0.32	0.98

Mulch	Cropping systems		
	C_1	C_2	C_3
M_1	8.01	22.07	10.20
M_2	8.07	24.70	10.49
	SEm±	CD (P=0.05)	
Mulch levels at the same levels of cropping systems	0.21	0.59	
Cropping systems at the same or different levels of mulch	0.39	1.20	

T_1, Zero tillage; T_2, conventional tillage; M_1, no mulch; M_2, crop residue mulch; C_1, Maize–wheat; C_2, baby corn + frenchbean – pea – summer squash; C_3, maize + soybean – *gobhi sarson* + *toria*; NS, non-significant was 17.3% and 12.4% higher under conventional tillage owing to higher yields of crops under favourable conditions provided by tillage operations (Ramesh *et al.,* 2014). Among the cropping systems, baby corn + frenchbean–pea–summer squash fetched the highest net returns (176.4%) and benefit: cost ratio (64.0%) over maize-wheat, followed by maize + soybean–*gobhi sarson* + *toria* besides higher cost of cultivation in these systems. Higher returns in these systems might be owing to the higher market price for frenchbean, pea, summer squash and soybean over traditional maize and wheat. Due to higher cost of residue applied and FYM, the net returns and benefit: cost ratio were lower under crop-residue mulch and INM as compared to no-mulch and recommended dose of fertilizer, respectively.

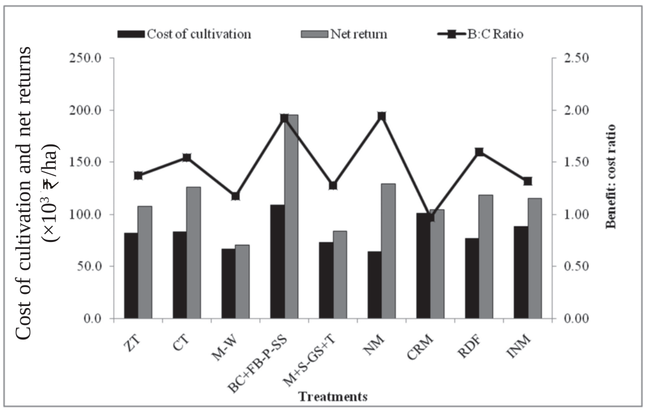

Fig. 1. Effect of resource-conservation technologies on economics of the system

Energetics

Energy-use pattern from different input sources

Energy inputs for the production of different season crops, as influenced by tillage, cropping systems, residue management and fertilizers, are given in Table 4. The results revealed that the input energy was comparable in tillage operations having the lowest input energy of 11.1 × 10^3 MJ/ha in the summer season and the highest values of 54.6 × 10^3 MJ/ha in the winter season. Besides having no-tillage operations in zero-tillage treatment, the input energy was comparable to conventional tillage due to higher labour requirement for manual weeding operations because of more weed population under zero tillage. Among the cropping systems, system-energy input was the highest under baby corn + frenchbean–pea–summer squash (29.3%), followed by maize + soybean–*gobhi sarson* + *toria* (5.4%) over maize–wheat cropping system. Higher energy inputs under these cropping systems were mainly due to higher amount of inputs, viz. seeds, fertilizers and

Table 4. Effect of resource-conservation technologies on energy analysis (pooled data of 2 years)

Treatment	Input energy (× 10^3 MJ/ha)				Output energy (× 10^3 MJ/ha)				Energy-use efficiency
	Rainy	Winter	Summer	System	Rainy	Winter	Summer	System	
Tillage									
ZT	45.8	54.2	11.1	111.1	181.9	54.4	33.3	269.6	5.98
CT	45.6	54.6	11.1	111.3	189.4	57.0	44.6	291.1	6.39
SEm±	–	–	–	–	3.76	3.21	1.28	5.16	0.13
CD (P=0.05)	–	–	–	–	NS	NS	4.0	16.3	NS
Cropping systems									
M-W	42.7	56.9	0.0	99.7	193.9	123.5	0.0	317.4	7.65
BC + FB – P – SS	44.9	50.6	33.4	128.9	146.0	6.2	117.0	269.2	5.40
M + S – GS + T	49.4	55.7	0.0	105.1	217.2	37.4	0.0	254.5	5.51
SEm±	–	–	–	–	4.61	3.93	1.57	3.62	0.16
CD (P=0.05)	–	–	–	–	14.5	12.4	5.0	19.9	0.51
Mulch									
NM	12.5	10.7	2.8	26.0	188.5	54.6	36.1	279.2	10.91
CRM	78.8	98.1	19.5	196.4	182.9	56.8	41.9	281.6	1.46
SEm±	–	–	–	–	2.19	0.71	0.61	2.34	0.11
CD (P=0.05)	–	–	–	–	NS	2.0	1.8	NS	0.33
Fertilizer									
RDF	46.7	54.7	11.2	112.7	181.1	54.4	38.2	273.7	5.63
INM	44.7	54.1	11.0	109.7	190.3	57.0	39.8	287.0	6.74
SEm±	–	–	–	–	2.19	0.71	0.61	2.34	0.11
CD (P=0.05)	–	–	–	–	6.3	2.0	NS	6.7	0.33

ZT, Zero Tillage; CT, conventional tillage; M–W, maize–wheat; BC + FB – P – SS, baby corn + frenchbean – pea – summer squash; M + S – GS + T, maize + soybean –*gobhi sarson* + *toria*; NM, no mulch; CRM, crop-residue mulch; RDF, recommended dose of fertilizer; INM, 75% RDF + 25% N through organic manure; NS, non-significant labour-intensive nature (Walia *et al.,* 2014). Application of crop-residue mulch consumed the highest system-input energy (655.4%) as compared to no-mulch treatment. Similarly, applying recommended dose of fertilizer consumed the highest system energy input as compared to integrated nutrient management due to higher energy equivalents of fertilizer.

Output energy

The crop-establishment techniques significantly influenced the output energy. Significantly higher system-output energy (7.9%) was recorded under conventional tillage owing to higher yield of individual crop than zero tillage. These results are in line with Singh *et al.* (2008) from Almora, Uttarakhand. Among the cropping systems, maize–wheat system recorded 24.7% highest system output energy than maize + soybean–*gobhi sarson* + *toria* and the lowest in baby corn + frenchbean–pea–summer squash. This was due to high energy equivalent of cereals with higher dry-matter production than vegetable crops. This clearly shows that the maize–wheat cropping system has its own importance and can not be given up completely. Rather the remunerative cropping systems should find a proportional share to meet out the urgent cash requirement of the farmers. Mulch treatments did not significantly influence the system-output energy. In case of fertilizer, significantly higher system-output energy was recorded under INM (4.9%) over RDF which was owed to greater yield under INM.

Energy-use efficiency

Tillage operations did not show any significant result on energy-use efficiency (EUE). Among cropping systems, maize–wheat recorded higher EUE (7.65) over baby corn + frenchbean–pea–summer squash cropping system (5.40). Higher EUE under a particular cropping system was mainly attributed to higher energy production with the use of relatively lesser energy. Application of the crop-residue mulch resulted in the lowest EUE (1.46) as compared to no-mulch (10.91) which might be due to very less energy input used in no-mulch as compared to crop-residue mulch which required higher amount of energy inputs in terms of crop residue. In case of fertilizer, INM resulted in higher EUE (6.74) than RDF which was due to high output energy under integrated nutrient management.

Energy indices

The energy indices presented in Table 5 showed that the

Table 5. Effect of resource-conservation technologies on energy indices (pooled data of 2 years)

Treatment	Net energy ($\times 10^3$ MJ/ha)	Energy productivity (kg/MJ)	Energy-output efficiency (MJ/ha/annum)	Specific energy (MJ/kg)	Energy intensity in physical terms (MJ/kg)	Energy intensity in economic terms (MJ/₹)
Tillage						
ZT	158.6	0.273	855.0	9.50	3.62	3.69
CT	179.8	0.308	923.2	9.35	3.42	3.86
SEm±	5.2	0.006	16.4	0.34	0.09	0.08
CD (P=0.05)	16.3	0.020	51.58	NS	NS	NS
Cropping systems						
M–W	217.7	0.192	1015.5	12.71	3.92	5.02
BC + FB – P – SS	140.4	0.457	848.8	5.39	2.43	2.61
M + S – GS + T	149.5	0.221	803.0	10.18	4.22	3.69
SEm±	6.3	0.008	20.05	0.41	0.11	0.10
CD (P=0.05)	19.9	0.024	63.17	1.30	0.34	0.32
Mulch						
NM	253.2	0.510	885.1	2.33	0.86	4.59
CRM	85.2	0.070	893.1	16.53	6.19	2.95
SEm±	2.3	0.005	7.31	0.23	0.07	0.04
CD (P=0.05)	6.7	0.013	NS	0.66	0.20	0.11
Fertilizer						
RDF	161.0	0.267	867.9	9.70	3.65	4.00
INM	177.3	0.313	910.3	9.15	3.39	3.55
SEm±	2.3	0.005	7.31	0.23	0.07	0.04
CD (P=0.05)	6.7	0.013	20.97	NS	0.20	0.11

ZT, Zero tillage; CT, conventional tillage; M–W, maize–wheat; BC + FB – P – SS, baby corn + frenchbean – pea – summer squash; M + S – GS + T, maize + soybean – *gobhi sarson* + *toria*; NM, no mulch; CRM, crop-residue mulch; RDF, recommended dose of fertilizer; INM, 75% RDF + 25% N through organic manure; NS, non-significant conventional tillage recorded significantly highest net energy (13.4%), energy productivity (12.8%), energy-output efficiency (7.9%) and energy intensity in economic terms (4.6%) over zero tillage. Among the cropping systems, significantly highest net energy (55.1%), energy-output efficiency (19.6%), specific energy (135.8%) and energy intensity in economic terms (92.3%) were recorded under maize–wheat over baby corn + frenchbean–pea–summer squash. This might be owing to lower energy input requirement (99.7×10^3 MJ/ha) of maize–wheat than the other cropping system. However, energy productivity was significantly highest under baby corn + frenchbean–pea–summer squash (138.0%) owing to higher production and higher MGEY in this cropping system as compared to traditional maize–wheat cropping system. However, energy intensity in physical terms was minimum under baby corn + frenchbean–pea–summer squash as compared to another cropping system. This may be due to the higher harvestable biomass. Thus there is sufficient scope to replace maize–wheat cropping system with other cropping systems without any decline in economic yield; rather, it improved substantially. In case of mulch, specific energy (610.4%) and energy intensity in physical terms (619.8%) were higher under crop-residue mulch, while net energy (197.2%), energy productivity (628.6%) and energy intensity in economic terms (55.6%) were higher under no-mulch. Fertilizers treatments also showed a similar trend where the net energy (10.1%), energy productivity (17.2%) and energy-output efficiency (4.9%) were higher under INM, while energy intensity in economic terms (12.7%) and energy intensity in physical terms (7.7%) were higher under RDF.

It was concluded that conventional tillage proved to be better in terms of maize grain-equivalent yield, biological yield and energy indices by providing more yield than zero tillage. Further, diversifying the existing cropping system with vegetable-based cropping system can be more profitable to the hill farmers and can provide more regular employment opportunities. However, diversification should find a proportional share to meet out the urgent cash, food and energy requirement of the farmers.

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