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Production and cropping system's influence on productivity, economic viability and energetics under mid hill conditions of Himachal Pradesh

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Abstract

The study was carried out in a continuing experiment under the aegis of *Rashtriya Krishi Vikas Yojna* at Palampur. Three cropping systems viz. maize- wheat, maize + cowpea- wheat + gram and okra + pole bean-cabbage + garden pea were evaluated under four production practices viz. integrated nutrient management (INM), organic management (OA), natural farming (NF), and conservation agriculture (CA) for crop productivity, profitability and energetics. Among production systems, INM or CA were more promising in terms of wheat grain equivalent yield (WGEY), net returns, energy output, energy intensity, energy productivity and energy profitability followed by OA and NF treatment in that order. INM and CA production practices increased WGEY by 2.54 and 1.86 times, net return by 6.14 and 5.31 times, energy output by 1.63 and 1.59, energy efficiency by 2.10 and 1.20, net energy by 1.80 and 1.62, energy productivity by 4.0 and 2.0 and energy profitability by 6.8 and 5.70 times, respectively over the NF production practice. Okra + pole bean – cabbage + garden pea gave significantly higher WGEY (13.7 Mg/ha/annum), energy productivity (0.4 kg WGEY/MJ) and energy profitability (INR 616/ha/day). But it had higher cost of cultivation and low yield in *kharif* thereby lower net returns, B:C, energy output, energy output: input and energy intensity both in terms of MJ/kg and MJ/rupee.

Key words: Production systems, Cropping systems, Energetics, economics, INM, organic, conservation agriculture, natural farming.

Sustainable resource management in agriculture is important for India's food and nutritional security. Crop diversification especially intensification can be a useful mean to increase crop output under different situations. Intensive cropping is the practice of producing maximum yield from a given area by growing of two or more crops on the same field in a year. Intensification of crops provides opportunity for optimizing crop production per unit area and time, ensuring food security, self-sufficiency, insurance against crop failure and judicious utilization of resources. There is a dire need to have efficient cropping systems under different production scenarios such as integrated nutrient management, conservation agriculture, organic farming and natural farming. Conventional methods of sowing, which requires excessive tillage delays the sowing and reduce the yield, but the same can be accomplished efficiently to save the time, fuel, energy and cost with use of improved machines, *viz*.zero, strip and rotavator till drill etc. (Jha *et al*. 2007).

Energy is one of the most important indicators of crop (Singh *et al*. 2008) and cropping system's performance. Agriculture itself is energy user and energy supplier in the form of bio-energy (Alam *et al*. 2005). Energetics is a mean to quantify and determine relationship between input and output energy to augment crop productivity and energy use efficiency. The net energy of a cropping system can be quantified for the sound planning of sustainable cropping systems (Chaudhary 2016). By using optimal level of energy input, yield of different crops can be increased upto 30%. The energy was invested in various forms such as mechanical (farm machines, animal/human labour), seeds, fertilizers, water management, herbicides, fungicides, insecticides and various organic and inorganic inputs. Through photosynthesis plant transform solar and chemical energy into storable chemical energy as carbohydrates, proteins, and fats in the shape of main (the products consumed by humans such as grains, fruits, pods etc) and by products (the products utilized for consumption by livestock such as straws, haulms, fodders etc).

The study of energetics, which is relatively a stable index unlike economics of production, assumes paramount importance in the present era of energy crisis. It can be used to evaluate a given cropping system. The approach reduces the various factors and forces involved in a cropping system for energy units and describe the production process as energy transformation (Shilpha *et al*. 2018). In crop production large share of energy is used for land preparation (20-25%), fertilizers (25-30%) and irrigation (25-35%), which require commercial non-renewable sources of energy like petroleum products. The non-renewable energy is expensive and liable to exhaust in near future. The steady decline in the energy-use efficiency in current agriculture is a matter of great concern. Keeping the above facts in mind the present study was undertaken to evaluate the alternative cropping systems under different production scenarios for productivity, profitability and energetic.

Materials and Methods

Experimental site

The field experiment was carried out in an on-going experiment at Palampur (32°6′ N latitude, 76°3′ E longitude and 1290 m altitude) during 2019-20 (rabi) and 2020 (*kharif*).The site is situated in Kangra district under mid hills sub humid agro-climatic zone of Himachal Pradesh, India. The soil of the test site was silty clay loam in texture, moderately acidic in response (5.8), low in organic carbon (0.72%), high in available P (41.1 kg/ha), medium in available K (198.7 kg/ha), and low in available N (270.5 kg/ha). The region receives an average rainfall of 2332 mm per annum. The major portion of the rainfall (about 80%) is received from June to September. Showers of winter rain are received from December to February. October, November, April and May are dry months and usually receive very low rainfall. Average evaporation was 2.7mm/day and 3.5mm/day for the period from October 2019 to May 2019 and May 2020 to October 2020, respectively. The average sunshine hours were 6.3 and 5.8/day during *rabi* (2019) and *kharif* (2020), respectively.

Experimental design and treatments

Three different cropping systems *viz*. maize – wheat, maize + cowpea – wheat + gram and okra + pole bean – cabbage + garden pea were evaluated under four production practices viz. integrated nutrient management (INM), organic management (OA), natural farming (NF), and conservation agriculture (CA) in a split plot design with three replications. The package of practices (Anon. 2018a; Anon. 2018b; Anon. 2018) of the university was used to serve as a basic guide especially for nutrients, water and weed management and other cultural practices in raising different crops under aforementioned cropping and production systems in the present study.

Field techniques

The experimental field was prepared with the help of power tiller and harrow. After the layout the experimental plots were prepared and levelled manually. The plots were ploughed individually after each season to avoid disrupting the plot bunds.

Recording of observations and economic and energy indices

The yield of each crop was expressed on hectare basis in mega gram/ha (Mg/ha). Net returns were calculated by subtracting the cost of cultivation from gross returns.

$$\text{Net returns (₹/ha)} = \text{Gross Returns (₹ha)} - \text{cost of cultivation (₹/ha)}$$

$$\text{B: C} = \frac{\text{Net returns from a treatment (₹/ha)}}{\text{Cost of cultivation of the treatment (₹/ha)}}$$

Energy input and output in different inputs/ operations/ main and byproducts, and other power sources *viz*. labour, fuel, machinery, fertilizer, seeds, pesticides, irrigation and crop yield were calculated by standard energy coefficients (Devasenapathy *et al*. 2009). To calculate the input energy, it was converted to energy equivalents by multiplying their per unit energy equivalents. The farm produce (seed yield+straw yield) was also converted into energy in terms of energy output (MJ) using average crop yield multiplied by their energy equivalents per unit. Based on the energy equivalents of the inputs and output, energy use efficiency, energy productivity, energy intensity in physical terms and energy intensity in economic terms were calculated as follow:

Energy efficiency = Energy output (MJ ha^{-1})/Energy input (MJ ha^{-1})$^{-1}$
Net energy (MJ ha^{-1}) = Energy output (MJ ha^{-1}) - Energy input (MJ ha^{-1})
Energy productivity (kg MJ^{-1}) = Output (grain + by product, kg ha^{-1})/Energy input (MJ ha^{-1})$^{-1}$
Energy intensity (in physical terms, MJ ha^{-1}) = Energy output (MJ ha^{-1})/ Output (grain + by product (kg ha^{-1})$^{-1}$
Energy intensity (in economic terms, MJ INR^{-1}) = Energy output (MJ ha^{-1})/ Cost of cultivation (INR ha^{-1})$^{-1}$

Statistical analysis

The data obtained was subjected to statistical treatment by analysis of variance (ANOVA) using split plot design to test the significance of the overall differences among the treatments by the "F" test and conclusion was drawn at 5% probability level. Standard error of mean was calculated in each case. When the 'F' value from analysis of variance tables was found to be significant, the least significant difference (LSD) was computed to test the significance of the difference between the two treatments.

Results and Discussion

Yield

The economic yields of crops (cob, grains, greens, or pod) under different treatments were converted to their wheat equivalents based on the market price of each product (Table 1). Among the production systems, the highest wheat grain equivalent (11.7 Mg/ha) was obtained in INM treatment which was followed by CA and OF (8.6 & 8.3 Mg/ha, respectively). Higher crop yields under INM treatment in comparison to organic and pure inorganic counterparts in the babycorn-Chinese sarson-onion cropping sequence have been earlier reported (Negi *et al*. 2015a; 2016). Similarly, in the rice-wheat system Negi, *et al*. (2015) found INM (where 50% N was supplied through FYM and 50% NPK was through fertilizers) better than pure inorganic. Cropping systems also brought about significant variation in wheat grain equivalent yield during both seasons and thereby yearly total. The Okra + Pole bean – cabbage + garden pea treatment resulted in the highest wheat grain equivalent yield because of more yield of the economic product. Maize – wheat and maize + cowpea – wheat + gram treatments under cropping systems were comparable to each other in terms of wheat equivalent yield. The superiority of vegetables based cropping systems over the traditional rice - wheat or maize -wheat cropping systems in terms of equivalent yields and economics has been well documented earlier from this location (Rana *et al*. 2010; 2011).

Table 1. Effect of production and cropping systems on wheat grain equivalent yield, economics, energy of main product and total energy output

Treatment		Wheat grain equivalent yield (Mg/ha)	Net returns (000, INR/ha)	B:C	Energy of main product (10^9 Cal/ha)	Total energy output (10^{11}J/ha)
	Production system					
P_1	Integrated nutrient management	11.7	228.9	1.6	12.67	3.6
P_2	Organic farming	8.3	121.6	0.7	9.30	3.2
P_3	Natural farming	4.6	37.3	0.3	6.19	2.2
P_4	Conservation agriculture	8.6	198.2	1.8	10.89	3.5
	SEm±	0.2	9.5	0.2	0.58	0.3
	LSD (P=0.05)	0.7	23.2	0.5	1.41	0.7
	Cropping system					
C_1	Maize - wheat	5.5	165.1	1.5	11.91	4.6
C_2	Maize + cowpea - wheat + gram	5.7	121.8	1.0	11.27	3.8
C_3	Okra + Pole bean - cabbage + pea	13.7	152.7	0.9	6.10	0.9
	SEm±	0.3	7.1	0.2	0.49	0.4
	LSD (P=0.05)	0.6	14.4	0.4	1.04	0.9

Economics

Net returns were significantly higher under INM (INR 228.9 thousands/ha/annum) followed by CA treatment (Table 1). This was due to higher system productivity of crops with growing two crops in a year. Negi *et al* (2016) have also found higher net returns and B:C from the babycorn-Chinese sarson-onion cropping system under INM management over the organic and pure inorganic nutrient management counterparts. On the contrary, the lowest returns were obtained in NF treatment (INR 37.3 thousands/ha) because of more cost of production especially on mulching. Among cropping systems total systems net returns were maximum under maize – wheat cropping system (INR 165.1 thousands/ha/annum). In spite of higher yield, vegetable based cropping system *viz*. okra + pole bean – cabbage + peas was next only after maize - wheat cropping sequence for accruing net returns owing to higher cost of cultivation. Maize + cowpea - wheat + gram cropping system resulted in lowest net returns amongst cropping systems. B:C ratio was in the order conservation agriculture > INM > OA > NF amongst the production systems and wheat – maize > maize + cowpea – wheat + gram > okra + pole bean – cabbage + peas amongst cropping systems.

Energetics

The main product during *rabi* season was wheat grains, gram seeds, cabbage heads and peas pods while during the *kharif* season these were maize cobs, cowpeas, okra and pole bean pods. The energy output of the main product obtained under various production/ cropping systems are presented in Table 1. Among the production systems, the energy of main product during *rabi* and *kharif* and thereby system's total was highest under INM followed by CA and OA. The lowest values of energy of main product were obtained in natural farming (NF) due to low yields of the main products. It is conclusively indicated that though yield and income from the vegetable based cropping systems such as okra + Pole bean – cabbage + peas was higher but these were poor energy yielders due to early harvesting of their tender edible parts which store more of water rather than carbohydrates, fats or proteins as compared to cereals/pulse based systems. Thus in a farming systems perspective, it is suggested to partly replace the cereals or pulse based systems with the remunerative vegetable based systems for income and nutritional security.

The total energy output is expected to be positively associated with the energy from the main product. The variation might be only owing to straws. It is indicated that values of total energy output in *kharif* season was more than in *rabi* season a reverse from the energy of the main product. This was owed to more energy from the straws of cereals and pulses. The production systems gave significant variation in the total energy output during *rabi* and *kharif* and thereby from the system as a whole. The INM, CA and OA treatments remaining at par with each other resulted in significantly higher system's total energy output over the NF treatment because of higher yield of the main and by products of crops. Season-wise and systems' total energy output also varied significantly due to cropping systems. System's total energy output was significantly higher in maize – wheat system followed by maize + cowpea – wheat + gram system. Okra + Pole bean – cabbage + garden pea cropping system like energy from the main product produced lower systems' total output energy because of lower energy values possessed by the tender vegetative main and by products.

The system's, maximum energy input was in CA certainly due to more energy invested in fertilizers, herbicides to check weed growth and manual weeding to take care of rest of the weeds (Table 2). This was followed by NF and INM under production systems. The least energy spent was in OA. Variation in the energy input under cropping systems was small ranging from 3.6 x 10^{10} J/ha under maize – wheat to 3.7 x 10^{10} J/ha under maize + cowpea – wheat + gram and okra + pole bean – cabbage + peas cropping systems. Higher energy input was also reported in rice varieties under conventional planting and semi-mechanized farming system (Yadav *et al*. 2013; Azarpour and Moraditochaee, 2013).

Table 2. Effect of production and cropping systems on total energy input, energy efficiency, net energy and energy productivity of different crops

Treatment		Total energy input (10^{10}J/ha)	Energy output: input (energy efficiency)	Net energy (10^{10}J/ha)	Energy productivity (kg wheat grain equivalent/MJ)
Production system					
P_1	Integrated nutrient management	3.1	11.6	32.7	0.4
P_2	Organic farming	2.3	14.0	29.3	0.4
P_3	Natural farming	4.0	5.5	18.1	0.1
P_4	Conservation agriculture	5.3	6.6	29.5	0.2
	SEm±	-	1.1	2.9	0.01
	LSD (P=0.05)	-	2.6	7.1	0.02
Cropping system					
C_1	Maize - wheat	3.6	14.2	42.8	0.2
C_2	Maize + cowpea - wheat + gram	3.7	11.3	34.1	0.2
C_3	Okra + Pole bean - cabbage + pea	3.7	2.8	5.3	0.4
	SEm±	-	1.2	4.1	0.01
	LSD (P=0.05)	-	2.5	8.6	0.02

When a system produces higher output energy and requires less input energy, it is considered more efficient. Among the production system significantly higher energy use efficiency (14.0), i.e. the ratio of energy output to energy input was obtained in OA followed by INM production systems. This was because maximum energy was produced in these treatments with least expenses of energy. Among cropping systems highest energy output: input was achieved with maize –wheat system followed by maize + cowpea – wheat + gram under cropping systems. Vegetable based cropping system viz. okra + pole bean – cabbage + peas was highly energy inefficient because of low overall energy output from the crops' main and by-products. The higher energy use efficiency of a crop was mainly attributed to higher energy production with the use of relatively lesser energy utilization under a particular sowing method (Jain *et al*. 2007).

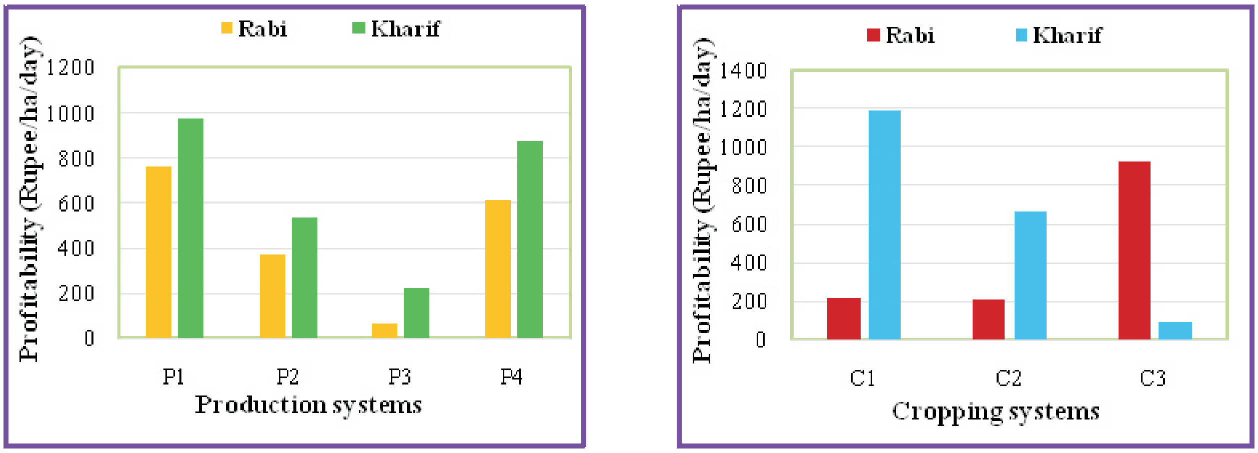
As a system's total net energy INM, CA and OF remaining at par with each other resulted in significantly higher net energy over the NF (18.1×10^{10} J/ha) treatment. Among cropping systems' highest total net energy was obtained in maize – wheat followed by maize +cowpea – wheat + gram. Okra + Pole bean – cabbage + garden pea (5.3×10^{10} J/ha) resulted in lowest total net energy.

The energy productivity, i.e. kg of wheat grain equivalent yield produced per unit of energy invested was higher under INM (P_1) and OF (P_2) treatments followed by CA and NF being statistically at par with each other. Among the cropping systems, vegetable based cropping system because of higher wheat grain equivalent yield gave significantly higher season-wise and systems total energy productivity over the cereal and cereal + pulse based cropping systems.

Under production and cropping systems, energy intensity of *kharif* season crops was much higher than rabi season crops. Under production systems, maximum energy intensity was obtained in NF treatment (56.3 MJ/kg) followed by OF treatment (54.9 MJ/kg). The lowest energy intensity in terms of MJ/kg was obtained in INM (47.2 MJ/kg) (Table 3). Among the cropping systems, maximum energy intensity was found in maize – wheat treatment (84.6 MJ/kg) followed by maize + cowpea – wheat + gram treatment (65.7 MJ/kg). The lowest intensity of energy (MJ/kg) was found in okra + pole bean – cabbage + garden pea treatment. The highest energy intensity (MJ/rupee) among the production systems, was found in conservation agriculture (3.5 MJ/rupee) which was at par with integrated nutrient management treatment (2.4 MJ/rupees). NF resulted in minimum energy intensity in terms of MJ/rupee among the production systems being comparable to organic agriculture treatment. Among cropping systems, the highest energy intensity (MJ/rupee) was worked out for maize – wheat treatment (4.2 MJ/rupee). Lowest energy intensity was found in okra + pole bean – cabbage + garden pea (0.5 MJ/rupee) as a total. Highest energy productivity was recorded in INM treatment (44 kg/ha/day). The second highest was in CA treatment (32 kg/ha/day) which was at par with OA treatment (31 kg/ha/day). Lowest productivity of energy was found in NF treatment (17 kg/ha/day) under production systems. Among the cropping systems, highest energy productivity was obtained in vegetable based cropping system both during *rabi* and *kharif* and thereby systems'. Maize – wheat and maize + cowpea – wheat + gram cropping systems were comparable in influencing the energy productivity (both 19 kg/ha/day). Energy productivity is in the order of sugar crops>cereals>oilseeds>pulses among the crop groups (Shilpha *et al.* 2018).The highest system's profitability (Table 3 and Fig 1) was achieved under CA treatment (710-rupee ha^{-1} day^{-1}) followed by INM treatment (844-rupee ha^{-1} day^{-1}). The lowest profitability was obtained under NF treatment (124-rupee ha^{-1} day^{-1}).

Table 3. Effect of production and cropping systems on energy intensity, energy productivity and energy profitability

Treatment		Energy intensity (MJ/kg)	Energy intensity (MJ/rupee)	Energy productivity (kg/ha/day)	Energy profitability (Rupee/ha/day)
Production system					
P$_1$	Integrated nutrient management	47.2	2.8	44	844
P$_2$	Organic farming	54.9	2.1	31	436
P$_3$	Natural farming	56.3	1.8	17	124
P$_4$	Conservation agriculture	50.8	3.5	32	710
	SEm±	0.49	0.38	0.78	0.31
	LSD (P=0.05)	1.03	0.92	1.90	0.76
Cropping system					
C$_1$	Maize - wheat	84.6	4.2	19	573
C$_2$	Maize + cowpea - wheat + gram	65.7	2.9	19	396
C$_3$	Okra + Pole bean - cabbage + pea	6.7	0.5	55	616
	SEm±	0.60	0.36	1.02	0.48
	LSD (P=0.05)	1.28	0.76	2.17	1.01



(a) (b)

Fig 1. Effect of production systems (a) and cropping systems (b) on profitability (Rupee/ha/day)

Conclusion

INM and CA production practices were found to the more productive, remunerative and energy efficient as compared to natural and even organic practices. Vegetable based sequence viz. okra + pole bean – cabbage + garden pea was more benefitting in terms of tonnage and monetary gains but small in energetic as compared to conventional cereal and cereal + pulse based sequences. Thus, complete replacement of cereal or cereal + pulse based systems for want of more monetary gains can neither be required nor be done.

Conflict of interest: The authors declare that there is no conflict of interest in this research paper.

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