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ENERGY EFFICIENCY AND ECONOMETRIC ANALYSIS OF ORGANIC KIWIFRUIT (*ACTINIDIA DELICIOSA* A. CHEV.) PRODUCTION

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Abstract

The energy exchange ratio of cultivation and different parameter values of input affecting the organic production of kiwifruit in the mid-hill Himalayan region of India during 2017 and 2018 was determined. The experimental trial was divided into 7 organic treatment *i.e.* T_1 to T_3 was sole application on equivalence 100 per cent Dairy manure (DM), Vermicompost (VC) and Poultry manure, T_4 to T_7 was a compound application of 50: 50 DM: PM, DM: VC and VC: PM and T_7 in which DM = PM = VC applied on N equivalence. Five foliar sprays of organic formulation were applied in each of the treatment. The Energy efficiency and econometric analysis of organic kiwifruit production were examined. The highest energy inputs unit per hectare was utilized by T_1 out of which over 86 per cent were from organic manure inputs and provided 26401.02 MJ/ha. The highest yield per hectare, as well as the output energy were observed in the treatment T_5. Whereas the highest energy ratio, energy productivity, and specific energy were recorded under T_2. Likewise, the highest productivity ratio and benefit-cost ratio were recorded under T_7 which was followed by T_2. From a farming point of view, the T_2 gave the superior result because it has provided optimum amount output along with maximum returns.

Introduction

The agricultural concept of 21st century relies on low cost crop production, increased nutrient use efficiency, and improving the environmental quality. The cultivation of kiwifruit under inorganic fertigation leads to increased cost of production, soil degradation, leaching of nutrients, and conversion of soil nutrients into non available form. However, kiwifruit has high nutritive value being a rich source of vitamin C. It has gained popularity due to potential health benefits, like a source of antioxidants, lowering of blood lipids and improvement of gastrointestinal laxation (Singletary 2012). The kiwifruit production strategy in mid hills of Himalayan region for future should be based on the high production with less use of input which will lead to increase farmer income and improve the soil quality. The main emphasis should be given on the conservation of natural resources like soil, water from the overuse of agrochemicals (Ayala and Rao 2002). It was estimated that 30 per cent of organic product of the world is present in India with cultivating 1.78 million hectares out of 69.8 million hectares of the total cultivated area (Willer *et al.* 2018). At the same time, maximum numbers of the farmers are struggling because of the poor policies of their government regarding organic products and low market demand. Organic farming maintains ecosystem service, therefore it is more sustainable than modern agriculture, which degrades some ecosystem services (Sandhu *et al.* 2008). Organic fruit production has gained momentum in recent years by consumer demand as well as higher price which have prompted producers to grow fruit crops organically. Organic kiwifruit farming is of paramount importance as there is less biotic and abiotic stress under mid hill condition. The

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kiwifruit orchardists are mainly dependent on different energy resources such as electricity, fuels, agrochemicals, etc. The use of energies in efficient way would lead to optimum quality fruit production and also contributes to the national economy and increase farmers profitability. The resulted outcome from plant (fruit and by products) is known as output energy. The development of input of system of energy compared to the output of products should therefore help to reduce the emissions of greenhouse gases (GHG's) in agricultural production (Kızılaslan 2009).

Energy efficiency contributes to the economy in the rural area with the competitiveness of sustainable agriculture, increased profitability, and productivity (Mohamaddi *et al.* 2010). In addition, the benefit-cost ratio, the use of direct and indirect energy, renewable and non-renewable energy were determined. Several researches have been performed on energy input- output analysis of agricultural products and the environmental impact of energy efficiency. For example, researches have been done on energy input-output analyses of organic fruit crops like citrus (Yilmaz and Aydin 2020), grape (Baran *et al.* 2017a), walnut (Baran *et al.* 2017b), mulberry (Gokdogan *et al.* 2017), lemon (Bilgili 2012), and cherry (Kizilaslan 2009). Although many experimental works have been done on energy input-output analysis in horticulture, there is no study on the energy input-output analysis of organic kiwifruit production. In the present study, the energy efficiency of kiwifruit production, net energy, energy productivity, and specific energy were assessed. Besides the energy input-output analysis of organic kiwifruit production was also evaluated. Since the information for kiwifruit cv. Allison is lacking, therefore, an effort was also made to compute data on energy use pattern, energy input, output ratio and economic analysis of kiwifruit production to help the growers.

Material and Methods

The experiment block was situated at an elevation of 1260 m above mean sea level with latitude of 30º 50' North and longitude of 77º11'30" East. The average annual rainfall of the area is about 100-130 cm. A field experiment was laid out by using randomized block design with 3 replications for 9 years old vine of kiwifruit cv, Allison at an experimental block of the Department of Fruit Science, Dr YS Parmar UHF, Nauni, Solan, HP, India. Data were recorded from seven different treatment combinations comprising 200 kg Dairy Manure (100% DM- T_1); 48.8 kg vermicompost- (100% VC- T_2), 33.0 kg poultry manure (100% PM-T_3), 100 kg DM + 16.50 kg PM (50:50- T_4), 100kg DM + 24.4 kg VC (50:50-T_5), 16.50kg PM + 24.4 kg VC (50:50 T_6), DM 66.50 kg + 8.250 kg PM +16.24 kg VC t (equal proportion-T_7) on N equivalence were in use for estimation of energy. In addition to these treatments, 5 sprays of liquid organic formulation were applied. Kiwifruit vines of the variety 'Allison' were carefully chosen for the experiment and were planted in 2009, T-bar trained, with rows oriented north-south at a spacing of 4.0 m × 6.0 m (416 vines/ha), the female: male ratio was 9:1 out which 376 were female.

The energy inputs were estimated based on the time required for each operation (schedule), a number of manpower, machinery and inputs used such as manures and liquid formulations (Tsatsarelis 1993). The energy equivalent of the inputs used in the production of the kiwifruit is presented in Table 1. The Energy used in cultural operations like tillage, irrigation, manures and foliar application, spraying, harvesting, transportation etc. in kiwifruit is also shown in Table 1. The human activity was calculated by this conversion factor *i.e.* one man-hour = 1.96 MJ/ha (Table 1). The energy effectiveness parameters were used to determine the relationship between energy consumption and total output and production per hectare. The Energy ratio, specific energy, energy productivity, energy intensiveness and net energy yield were measured as recommended by Mani *et al.* (2007). This ratio is generally higher in lower and higher energy input, which indicates the law of diminishing return. Gross profit, net return and benefit cost ratio was worked out keeping sale price of kiwifruit 1.34 $/kg. Energy efficiency is a useful tool to measure economic efficiency of crop production.

Energy Ratio	=	energy output (MJ/ha)/ energy input (MJ/ha)
Specific energy	=	energy input (MJ/ha)/ output (MJ/ha)
Energy productivity	=	output (kg/ha)/energy input (MJ/ha)
Net energy yield	=	energy output (MJ/ha) **-** energy input (MJ /ha)

Production value, gross profit, productivity, net return and benefit cost ratio was worked out as per following formula.

Total production value	=	Kiwifruit yield (kg/ha), *Kiwifruit price ($/kg)
Gross profit	=	Total production value ($/ha) – Total production costs ($/ha)
Productivity	=	Kiwifruit yield (kg/ha)/Total production costs ($/ha)
Net return	=	Total production value ($/ha) – Total production cost ($/ha)
Benefit-cost ratio	=	Total production value (kg/ha)/Total production cost ($/ha)
Net energy yield	=	energy output (MJ/ha) **-** energy input (MJ /ha)

Table 1. Energy equivalents of inputs and output in organic kiwifruit production.

Inputs	Unit	Energy equivalent (MJ unit^{-1})	References
Human labour	H	1.96	Mohamaddi *et al.* 2010
Soil application	H	1.96	
Spraying	H	1.96	
Cultural practices	H	1.96	
Harvesting	H	1.96	
Transportation	H	1.96	
Machinery	H	41.4	
Farmyard manure	Kg	.30	Ram and Verma 2017
Poultry manure	Kg	.50	
Vermicompost (kg)	Kg	.50	
Panchgavya	Kg	1.0	
Jeevamrit	L	1.0	
Diesel-oil	L	56.31	Ozkan *et al.* 2004
Electricity	kWh	11.93	
Irrigation water	m^3	.63	
Output			
Kiwifruit	Kg	1.90	Mohamaddi *et al.* 2010

Results and Discussion

The total energy consumed (Table 3) in terms of manpower, machinery and organic manures was 26401.02 with application of 100 % DM T_1 which was followed by the $T_5 > T_4 > T_7 > T_2 > T_6 > T_3$, recording 23267.26, 21493.94, 20194.75, 17539.54 and 15809.34 Mj per hectare respectively. It is apparent from the data that energy consumption with 200 kg/vine FYM was the highest (26401.02 MJ) (Table 2). The various input namely human labour consumed the highest energy after organic manures as compared to irrigation in all treatments of kiwifruit production, machinery consumed approx. same input energy in all the treatments, (Table 2). The percentage usage of unit energy per hectare followed the same trend as followed energy input provided. Organic manures were the highest energy-consuming input and varied from 12379.22 to 26401.02 MJ/ha in all the treatments. This might be due to the high transportation cost of the bulky organic manures. Similar results were reported by many researchers in different crops, parallel result of energy use in machinery and higher energy use for organic manures in various fruits crop production (Pimental *et al*. 1983; Strapatsa *et al.* 2006). Lower energy in machinery and diesel were reported for moderate high yield plantation of apple orchards in the eastern US (Pimental *et al.* 1983) because organic manures reduce incidence weeding and hoeing ploughing and improve the water capacity of the soil.

Table 2. Amount of unit requirement and energy input along with per cent share of input energy.

	Unit/ ha						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Human labour	1020	950	945	1002	1010	975	998
Machinery	13.55	13.55	13.55	13.55	13.55	13.55	13.55
Organic manures	75200	18348	12408	43804	46774.4	15378.4	35318.8
Diesel oil	12	12	12	12	12	12	12
Irrigation	600.13	600.13	600.13	600.13	600.13	600.13	600.13
Spraying	5	5	5	5	5	5	5
	Energy input MJ/ha						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Human labour	1999.2	1862	1852.2	1963.92	1979.6	1911	1956.08
Machinery	560.97	560.97	560.97	560.97	560.97	560.97	560.97
Organic manures	22560	9174.4	8685.6	15622.8	15867	8929	13472.3
Diesel oil	675.72	675.72	675.72	675.72	675.72	675.72	675.72
Irrigation	600.13	600.13	600.13	600.13	600.13	600.13	600.13
Spraying	5	5	5	5	5	5	5
	26401.02	12878.22	12379.62	19428.54	19688.42	12681.82	17270.2
	Percentage of Energy Input used						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Human labour	7.57	14.45	14.96	10.10	10.05	15.06	11.32
Machinery	2.12	4.35	4.53	2.88	2.84	4.42	3.24
Organic manures	85.45	71.23	70.16	80.41	80.59	70.40	78.00
Diesel oil	2.55	5.24	5.45	3.47	3.43	5.32	3.91
Irrigation	2.27	4.66	4.84	3.08	3.04	4.73	3.47
Spraying	0.01	0.03	0.04	0.02	0.02	0.03	0.02
Total % age	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 3. Amount of energy outputs in kiwifruit production with specific references to yield and econometric analysis (MJ/ha).

Code	Yield (Kg)		Energy output MJ/ha	Energy input MJ/ha	Energy ratio	Energy productivity	Specific energy	Net energy MJ/ha	Total production value ($)	Cost of cultivation ($)*	Gross profit ($)*	Productivity value	B:C ratio
	Per Vine	Kg per hectare											
T_1	37.11	13953.36	26511.384	26401.02	1.00	0.52	1.89	110.36	18697.50	10347.05	8350.44	1.34	1.80
T_2	38.88	14618.88	27775.872	12878.22	2.15	1.13	0.88	14897.65	19589.29	8555.24	11034.05	1.70	2.28
T_3	28.05	10546.8	20038.92	12379.62	1.61	0.85	1.17	7659.30	14132.71	6660.20	7472.50	1.58	2.12
T_4	30.01	11283.76	21439.144	19428.54	1.10	0.58	1.72	2010.60	15120.23	7198.57	7921.66	1.56	2.10
T_5	40.41	15194.16	28868.904	19688.42	1.46	0.77	1.29	9180.48	20360.17	10816.85	9543.31	1.40	1.88
T_6	32.41	12186.16	23153.704	12681.82	1.82	0.96	1.04	10471.88	16329.45	7578.985	8750.46	1.60	2.15
T_7	34.33	12908.08	24525.352	17270.2	1.42	0.74	1.33	7255.15	17296.8272	7331.21	9965.61	1.76	2.36

*Values in US dollars ($).

The new method of energy combines with usual concepts of economics to evaluate and optimize the design and performance of energy systems. Energy analysis and economical production system could be the more inclusive mode for the best management strategies. The highest crop yield and energy output (Table 3) was recorded with the T_5 i.e. application DM along with vermicompost which was followed by T_2. The highest energy ratio, energy productivity net energy and gross profit were recorded with the application of vermicompost (100%) on N equivalence, recording 2.15, 1.13 14897.65 MJ/ ha and 11034.05 $, respectively. Whereas, the lowest value of specific energy was observed with T_2.

The cost-economics analysis of kiwifruit production is presented in Table 3. The observation showed that the total production value (20360.17 $/ha) was the highest with the application of 50 per cent DM and 50 per cent VC (T_5). The highest productivity value (0.431) and benefit cost ratio (2.36) was found with the application of DM, VC and PM which was followed by T_2 . Similar studies were also conducted previously to determine energy usage efficiency in organic apricot, banana, apple production, and the energy usage efficiency value by Yilmaz and Aydin (2020). Organic kiwifruit production is a profitable production in terms of energy usage efficiency. Some of the benefits desired to be obtained through energy input/output analysis are summarized as: being able to evaluation whether energy has been used effectively or not. Once this is determined, then energy wastage will be avoided, as use of excessive energy will be avoided, which in turn, will lower the negative effects caused by environmental exposure of excessive energy, fuel, etc. in peach (Göktolga *et al*. 2006). Demircan *et al*. (2006) reported that proper tractor selection and management of machinery to decrease direct use of diesel fuel are needed to save non-renewable energy sources without impairing the yield or profitability of sweet cherry production. Similar results on the energy input-output analyses of organic fruit crops were also reported for several crops, like grape (Baran *et al*. 2017a), walnut (Baran *et al*. 2017b) mulberry (Gokdogan *et al*. 2017), lemon (Bilgili 2012), kiwifruit (Mohamadi *et al*. 2010) and cherry (Kizilaslan 2009).

In conclusion, various energy analyses based on input and output sources pattern were done in kiwifruit production system. Organic production system is an emerging system towards the approach of sustainable fruit product. The highest energy inputs units per hectare were utilized by T_1 out of which over 86 per cent were from organic manure inputs. The highest yield per hectare, as well as the output energy, were observed in the treatment T_5 which was followed by T_2. Whereas, the highest energy ratio, energy productivity, and specific energy were recorded under T_2. Likewise, the highest productivity ratio and benefit-cost ratio recorded under T_7 was followed by T_2. Therefore, T_2 gave the superior result as because the treatment provided optimum amount of output along with maximum returns.

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