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Study on energy use pattern of papaya production based on scheduling of irrigation and fertigation under drip

Dr. BL Sinha and Shashikant

Abstract

Efficient use of energy especially in agriculture is one of the vital important issues in most countries. Today’s agricultural production relies greatly on the consumption of non-renewable energies such as fossil fuel. Energy Audit attempts to balance the total energy inputs with its use and serves to identify all the energy streams in the systems and quantifies energy usages according to its discrete function. Energy Audit helps in energy cost optimization, water control, safety aspects and suggests the methods to improve the operating & maintenance practices of the system. Hence, a field experiment was conducted to work out the energy requirement for cultivation of papaya under drip irrigation with different fertigation levels during the year 2020-21 at Borsi Instructional Farm of Dau Kalyan Singh College of Agriculture and Research Station, IGKV, Bhatapara (C.G.). The experiment was laid out in the randomized block design with nine treatments combinations and three replications. The experiment comprised of nine treatments under drip method of irrigation with combination of three irrigation regimes viz. 60, 80 and 100 percent of cumulative pan evaporation (CPE), three different levels of fertilizer 80, 100 and 120 percent of recommended dose of fertilizer (RFD). Energy equivalents (extracted from scientific source) were used to calculate energy balance and indices. The results on energy use pattern depicted that maximum input energy, output energy, energy ratio input and energy productivity were found to be 135195 MJ ha^{-1}, 405919.8 MJ ha^{-1}, 3.00, and 1.06 kg MJ^{-1} respectively in treatment irrigation of 100 percent of CPE and fertigation of 120 percent of RDF. It was also found that the minimum energy of 0.95 MJ was required to produce one kg of papaya in this treatment.

Keywords: Papaya crop, energy use pattern

Introduction

Energy is a key input in agriculture production, as it is closely linked with the energy inputs. It is utilized in different forms such as mechanical (farm machines), human energy, draft animal energy, chemical fertilizer (pesticides, herbicides, insecticides), electrical moter for irrigation. The quantity of energy applied in agriculture operations needs to be remarkably more in order to feed the increasing population and to gain the added social and economic objectives. Adequate availabness of the appropriate energy and its effectual and efficacious use are essantial for increased agriculture response. It is noticed that crop response and food requirements are directly associted with energy. Energy is nedded in the farm for operating various tools, machines and for different agricultural operations. While flexible power is applied for performing field workss, the fixed power is applied for elevating water and irrigating field, threshings, selling, cleaning, grading and other related agricultural operations

Efficient use of energy is one of the principal requirements of sustainable agriculture. Energy use in agriculture has been increasing in response to increasing population, limited supply of arable land, and a desire for higher standards of living (Uhlin, 1998) [13] most especially to boost food security. Continuous increase in demands of food products have resulted in intensive use of chemical fertilizers, pesticides, agricultural machinery, and other natural resources. This does not come without any adverse effects because intensive use of energy causes problems threatening public health and environmental hazards. Efficient use of energy in agriculture will minimize environmental problems, prevent destruction of natural resources, and promote sustainable agriculture as an economical production system (Uhlin, 1998) [13]. Agriculture uses energy directly as fuel or electricity to operate machinery and equipment, to heat or cool buildings, and for lighting on the farm, and indirectly in the fertilizers and chemicals produced off the farm (Jekayinfa, and Bamgboye. 2006) [3]. Energy’s share of agricultural production expenses varies widely by activity, production practice, and locality.

Energy life cycle analysis is usually used to evaluate the efficiency and environmental impacts of the production systems (Uhlin, 1998) [13]. Considerable studies have been conducted on energy use in agriculture (Uhlin, H. E. 1998; Singh 2002; Mandal *et al*. 2002; Singh and Singh 2004: Jekayinfa and Bamgboye, 2006; Alipour *et al*. 2012: Ram and Kumar 2015 Fadara *et al*. 2019) [3, 13, 10, 5, 9, 1, 7, 14]. In recent times, the need for cost-effective energy saving technologies or practices is being recognized by many governments and manufacturing industries, hence forcing them to review their energy policies. This accounts for the extensive energy-related research work that has been done on many industrial systems with the aim of analyzing, improving the design and optimizing the performance of energy systems.

The energy analysis is based on the first law of thermodynamics, which expressed the principle of the conservation of energy. It is required to improve the design and performance of energy-transfer system, the aim of this study therefore was to determine the total amount of input–output energy used in papaya production in IGKV research farms in Chhattisgarh, investigate the distribution of different energies utilized during management practices, and evaluate the efficiency of input energy consumption.

Materials and Methods

A field experiment was conducted at Borsi research farm, Dau Kalyan Singh agriculture college and research station, Bhatpara (IGKV, Raipur) Chhattisgarh during the July 2020 to may 2021. The experimental site is situated in the central part of Chhattisgarh in India. In this location the mean minimum temperature 10 °C and mean maximum temperature is 43 °C. The average relative humidity is 60.43 percent and average wind velocity is 2.10 ms^{-1}. Te experiment site has sandy loam soil and falls under the semiarid zone. The experiment field was 88.8 m long and 46.2 m wide. The row to row spacing 1.65 m and plant to plant spacing 2.4 m. Recommended cultural operation are followed in raising the crops. The mean value obtained was used for estimating analysis of critical difference. These investigations were carried out using nine treatments with three replications. Treatments were tested in randomized block design. The details of treatments are given below.

Irrigation treatments for papaya crop

I_1 - Drip irrigation at 0.60 of cumulative pan evaporation
I_2 - Drip irrigation at 0.80 of cumulative pan evaporation
I_3 - Drip irrigation at 1.00 of cumulative pan evaporation

Fertigation treatments for Papaya crop

F_1 - 80% of Recommended Dose of Fertilizer
F_2 - 100% of Recommended Dose of Fertilizer
F_3 - 120% of Recommended Dose of Fertilizer

Treatment Combinations: Nine treatment combinations were as follows-T_1: Drip irrigation at 0.6 CPE + 80% RDF; T_2: Drip irrigation at 0.6 CPE + 100% RDF; T_3: Drip irrigation at 0.6 CPE + 120% RDF; T_4: Drip irrigation at 0.8 CPE + 80% RDF; T_5:Drip irrigation at 0.8 CPE + 100% RDF; T_6: Drip irrigation at 0.8 CPE + 120% RDF; T_7: Drip irrigation at 1.0 CPE + 80% RDF; T_8: Drip irrigation at 1.0 CPE + 100% RDF; and T_9: Drip irrigation at 1.0 CPE + 120% RDF

Energy use Pattern

Energy indices provide some basic measures of input energy, output energy, energy ratio, specific energy, energy productivity, and net energy were calculated on per hectare.

Energy input (MJ ha^{-1}): It is summation of energy required during crop production.

Energy output (MJ ha^{-1}): it is obtained by total crop yield multiplied by respective energy coefficient of the crop production.

Energy ratio: It is the ratio of energy output to the energy input used for raising a crop in an area.

$$\text{Energy ratio} = \frac{energy\ output}{energy\ input} \quad \ldots (1)$$

Specific energy: specific energy has been express the quantity of energy invested to produced a unit quantity of the product

$$\text{Specific energy} = \frac{Energy\ input}{Yield} \quad \ldots (2)$$

Where, Yield is taken in kg ha^{-1}

Energy productivity: it measures the quantity of product produced per unit of input energy. This is the inverse of the specific energy.

$$\text{Energy productivity} = \frac{Yield}{Energy\ input} \quad \ldots (3)$$

Result and Discussion

Input Energy of Production of Papaya

The treatment wise input energy for papaya production was presented in the Table 1 and Figure 1 and 2. From the table it was observed that the input energy were found to be 89866.2, 94658.5, 99452.8, 107870, 112668, 117470, 125571, 130389 and 135195 MJ ha^{-1} under the treatments T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8 and T_9, respectively. It was observed that 100 percent irrigation level had the highest input energy followed by, 80 percent irrigation level and minimum input was observed in 60 percent irrigation level. Similarly 120 percent RDF had highest input energy followed by 100 percent RDF and minimum input was observed in 80 percent RDF. The data regarding different irrigation and fertgation levels, input energy for papaya crop under 60 percent irrigation level and 80 percent fertigation level (T1) was found to be minimum input energy of 89866.2 MJ ha-1 while the maximum input energy was 135195 MJ ha-1 in treatment 100 percent irrigation level and 120 percent fertigation level (T9). Similar results have been reported by Chilur *et al*. 2017 [2] and Powar *et al*. 2017 [6].

Table 1: Effect of different irrigation and fertigation levels on input energy and output energy for cultivation of Papaya crop

Treatments	Input energy MJ ha^{-1}	Output energy MJ ha^{-1}
T$_1$:Drip irrigation at 0.6 CPE + 80% RDF	89866.20	179896.28
T$_2$: Drip irrigation at 0.6 CPE + 100% RDF	94658.50	217152.90
T$_3$: Drip irrigation at 0.6 CPE + 120% RDF	99452.80	240713.28
T$_4$: Drip irrigation at 0.8 CPE + 80% RDF	107870.00	273215.25
T$_5$:Drip irrigation at 0.8 CPE + 100% RDF	112668.00	289579.78
T$_6$: Drip irrigation at 0.8 CPE + 120% RDF	117470.00	301956.06
T$_7$: Drip irrigation at 1.0 CPE + 80% RDF	125571.00	326580.93
T$_8$: Drip irrigation at 1.0 CPE + 100% RDF	130389.00	340632.00
T$_9$:Drip irrigation at 1.0 CPE + 120% RDF	135195.00	405919.8.0

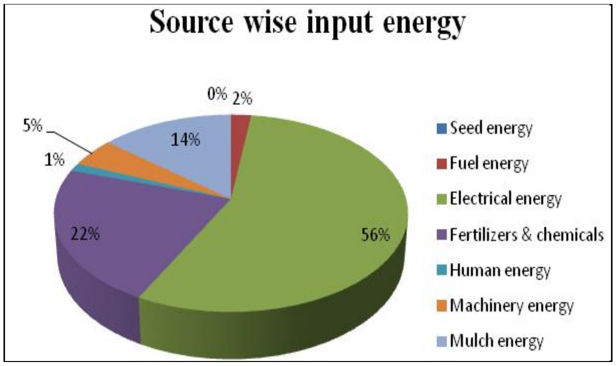

Fig 1: Source wise input energy at treatment T$_1$

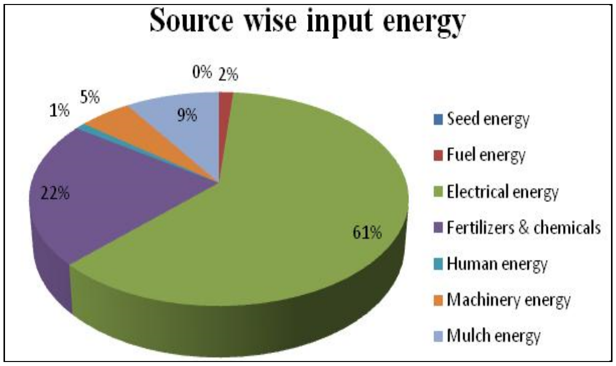

Fig 2: Source wise input energy at treatment T$_9$

Output Energy of Papaya

The effect of various treatments of irrigation and fertigation levels on the output energy of papaya was calculated and shown in Table 1 and Figure 3. The out energy were 179896.28, 217152.90, 240713.28, 273215.25, 289579.78, 301956.06, 326580.93, 340632.00 and 405919.80 in treatments T$_1$, T$_2$, T$_3$, T$_4$, T$_5$, T$_6$, T$_7$, T$_8$ and T$_9$, respectively.

The combined effect of irrigation and fertilizer was also observed that the highest output energy (405919.80 MJ ha^{-1}) was observed in 100 percent irrigation level and 120 percent fertigation level(T$_9$) and lowest output energy (179896.28 MJ ha^{-1}) was recorded in 60 percent irrigation level 80 percent fertigation level(T$_1$). The results are in conformity with the findings of Ram *et al.* 2017 and Powar *et al*. 2017 [7, 6]

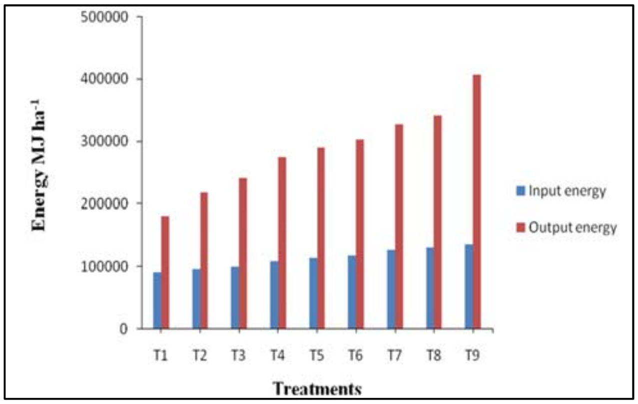

Fig 3: Treatment wise input and output energy for papaya production

Energy Ratio

The energy ratio analyzed in the papaya crop was presented in the Table 2 and Fig. 4. Energy ratio is ratio of total output energy to total input energy and found to be 2.00, 2.29, 2.42, 2.53, 2.57, 2.57, 2.60, 2.61 and 3.00 in T1, T2, T3, T4, T5, T6, T7, T8 and T9, respectively. The highest energy ratio (3.00) was observed in 100 percent irrigation level and 120 percent fertigetion level (T9) while the minimum (2.00) was in 60 percent of the irrigation level and 80 percent fertigation level. Similar findings have been reported by Chilur *et al.* 2017 [2], Powar *et al*. 2017 [6] and Sinha *et al.,* 2019 [11].

Table 2: Effect of different irrigation and fertigation levels on energy ratio, specific energy and energy productivity for cultivation of Papaya crop

Treatments	Energy ratio	Specific energy MJ kg^{-1}	Energy productivity kg MJ^{-1}
T$_1$:Drip irrigation at 0.6 CPE + 80% RDF	2.00	1.42	0.71
T$_2$: Drip irrigation at 0.6 CPE + 100% RDF	2.29	1.24	0.81
T$_3$: Drip irrigation at 0.6 CPE + 120% RDF	2.42	1.17	0.85
T$_4$: Drip irrigation at 0.8 CPE + 80% RDF	2.53	1.12	0.89
T$_5$:Drip irrigation at 0.8 CPE + 100% RDF	2.57	1.10	0.91
T$_6$: Drip irrigation at 0.8 CPE + 120% RDF	2.57	1.10	0.91
T$_7$: Drip irrigation at 1.0 CPE + 80% RDF	2.60	1.09	0.92
T$_8$: Drip irrigation at 1.0 CPE + 100% RDF	2.61	1.09	0.92
T$_9$:Drip irrigation at 1.0 CPE + 120% RDF	3.00	0.95	1.06

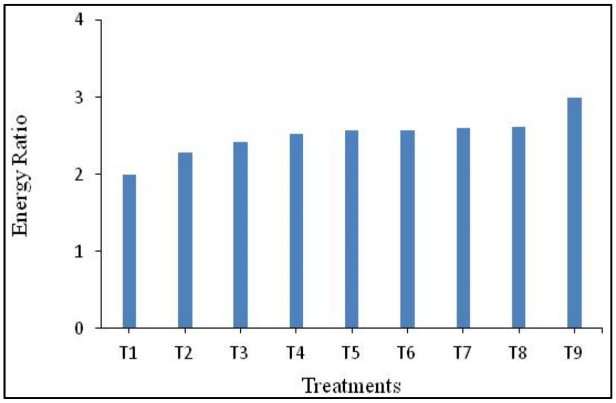

Fig 4: Treatment wise energy ratio for papaya production

Specific Energy for Production of Papaya

It is evident from the data presented in the Table 2 and Fig.5 that the specific energy was calculated as 1.42 MJ kg^{-1} which demonstrated higher specific energy in treatment T_1 and lower specific energy was observed 0.95 MJ kg^{-1} at treatment T_9.

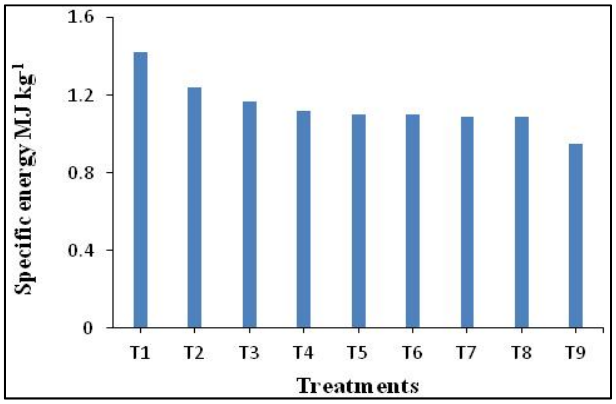

Fig 5: Treatment wise specific energy for papaya cultivation

It was observed that 100 percent irrigation level had the lowest specific energy followed by, 80 percent irrigation level and highest specific energy was observed in 60 percent irrigation level. Similarly 120 percent RDF had lowest specific energy followed by 100 percent RDF and highest specific energy was observed in 80 percent RDF. Similar results have been observed by Chilur *et al.* 2017 [2] and Powar *et al.* 2017 [6].

Energy Productivity for Papaya Cultivation

In regard to energy productivity was presented in Table 2 and Fig. 6 which depicts that maximum energy productivity was 1.06 kg MJ^{-1} 1n treatment T_9 and minimum of 0.71 kg MJ^{-1} in treatment T_1. The energy productivity increases as increasing the yield and decreasing the input energy. The energy productivity index with combination of three irrigation levels are 60, 80 and 100% of CPE is shown in table. It was observed that 100 percent irrigation level had the highest energy productivity index followed by, 80 percent irrigation level and minimum was observed in 60 percent irrigation level. Similarly 120 percent RDF had highest energy productivity index followed by 100 percent RDF and minimum was observed in 80 percent RDF. The results are in conformity with the findings of Ram *et al.* 2015, Chilur *et al.* 2017 [2] and Powar *et al.* 2017 [6]

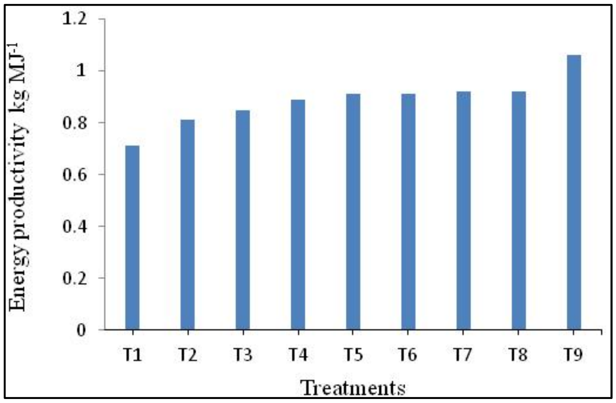

Fig 6: Treatment wise energy productivity

Conclusions

It may be concluded that the energy utilization under drip irrigation systems can be quantified and stratified for sound planning of sustainable systems for production of papaya in Bhatapara region of Chhattisgarh plain. The results depicted that maximum input energy, output energy, energy ratio input and energy productivity were found to be 135195 MJ ha^{-1}, 405919.8 MJ ha^{-1}, 3.00, and 1.06 kg MJ^{-1} respectively in treatment irrigation of 100 percent of CPE and fertigation of 120 percent of RDF (T_9). It was also found that minimum energy of 0.95 MJ was required to produce one kg of papaya in this treatment. The energy-water productivity is an integrated indicator of water and energy use in agricultural production systems. It captures the efficiency of systems which are energy intensive as well as water scarce. The data gathered from the study will help the farmers of the region to calculate irrigation inputs as diesel or electrical energy and guide them for operating the system efficiently.

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