International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(6): 869-871

Received: 19-09-2019
Accepted: 21-10-2019

Energy utilization in rapeseed cultivation under different irrigation scheduling and planting geometry

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Abstract
A detailed study on energy utilization in production agriculture was conducted at Assam Agricultural University, Jorhat, during *rabi* season of 2016-2017 and 2017-18 with four irrigation schedulings *viz*., irrigation at flower initiation stage; irrigation at flower initiation and 50% flowering stage; irrigation at flower initiation, 50% flowering and at siliqua development stage and rainfed with four different planting geometry *viz*., 30 cm × 30 cm, 30 cm × 25 cm, 25 cm × 25 cm and 30 cm × 5-7 cm. Application of irrigation at flower initiation, 50% flowering and at siliqua development stage recorded higher net return of energy (NER), whereas, energy productivity (EP) and energy use efficiency (EUE) was found highest at irrigation at flower initiation and 50% flowering stage. The lowest NER, EP and EUE were reordered under rainfed treatment. Among the planting geometries 25 cm × 25 cm recorded the highest NER, EP and EUE. However, specific energy (SE) was highest under rainfed and planting geometry 30 cm x 5-7 cm.

Keywords: Energy, irrigation scheduling, planting geometry, net energy return

Introduction

Agriculture, as a production-oriented sector, requires energy as an important input to production. Energy as an input is used right from ploughing of the land, sowing, intercultural operations, irrigation, harvesting and till threshing of the crop. Energy is invested in various forms such as mechanical (farm machines, human labour, animal draft), chemical (fertilizer, pesticides, herbicides), electrical, etc (Chaudhary *et al*., 2006) [4]. In developing countries like India, farm mechanization is a prime necessity to reduce human drudgery and to increase the output per unit area. An energy analysis acts as an indicator for the sustainable cropping system. The use of biomass as a source of renewable energy has attracted attention to bring more and more area under biomass oriented cropping. Energy approach in plant nutrition focuses on efficient utilization of energy through different sources of plant nutrition. The energy inputs and methods need to be evaluated to know their effectiveness and efficiency for future conservation of scarce natural resources (Amare and Endalew, 2016) [1]. The research knowledge on energy utilization and efficiency is scarce and scanty. This experiment is, therefore, undertaken to study the relationship between energy input and output of crops under different irrigation scheduling and planting geometry.

Materials and Methods

The assessment of energy requirements of rapeseed crop under different irrigation scheduling and planting geometry was carried out at the ICR Farm of Assam Agricultural University, Jorhat (26°47′ N latitude, 94°12′ E longitude and at an altitude of 87.0 meter above mean sea level). The experimental soil was sandy loam in texture with bulk density of 1.46 g/cc. The soil contained 181 kg/ha available N, 25 kg/ha available P_2O_5 and 120.5 kg/ha available K_2O and was acidic in reaction (pH=5.2). The experiment was laid out in split plot design with 3 replications. The size of the experimental plots were 12 m^2 (4 m × 3 m). The main plot treatment included four irrigation scheduling treatments *viz*. I_1: irrigation at flower initiation, I2: irrigation at flower initiation and 50% flowering, I_3: irrigation at flower initiation, 50% flowering and siliqua development and I_4: rainfed. The subplot treatment included different levels of planting geometry *viz*. S_1: 30 cm × 30 cm, S_2: 30 cm × 25 cm, S_3: 25 cm × 25 cm and

S_4: 30 cm × 5-7 cm. The nutrients N, P_2O_5 and K_2O @ 60-40-40 kg/ha were applied in the form of urea, single super phosphate and muriate of potash, respectively and Borax @ 10 kg/ha was applied to all the treatments at the time of sowing. The crop (var. TS-38) was sown on 23 October and 10 November and harvested on 25 January and 12 February during 2016-17 and 2017-18, respectively.

Energy input and output were calculated from the recorded data for each item of operations (expressed in MJ/ha), taking standard values suggested by Panesar and Bhatnagar (1994) [6]. Net Energy Return (NER), Energy Use Efficiency (EUE), Energy Productivity (EP) and Specific Energy (SE) were calculated as follows:

$$\text{NER} = \text{Energy Output} - \text{Energy Input}$$

$$\text{EUE} = \frac{\text{Energy Output}}{\text{Energy Input}}$$

$$\text{EP} = \frac{\text{Grain yield}}{\text{Energy Input}}$$

$$\text{SE} = \frac{\text{Energy Input}}{\text{Grain Yield}}$$

Results and Discussion

Energy input-output analysis

The consumption of energy in rapeseed cultivation under different irrigation scheduling and planting geometry are presented in Table 1.

Under different irrigation schedules, the highest total energy input was found in irrigation at flower initiation, 50% flowering and siliqua development (I_3) [18473 MJ/ha] followed by irrigation at flower initiation and 50% flowering (I_2) [17335 MJ/ha], irrigation at flower initiation (I_1) [15997 MJ/ha] and the lowest energy consumption was under rainfed (I_4) [14459 MJ/ha]. Scheduling irrigation at flower initiation, 50% flowering and at siliqua development stage required 1138, 2476 and 4014 MJ higher energy per ha as compared to irrigation at flower initiation; irrigation at flower initiation and 50% flowering and rainfed grown crop respectively. The increase in energy input in I_1, I_2 and I_3 as compared to rainfed was mainly due to more diesel and labour requirements for irrigation.

The total energy output was calculated by adding the seed and stover energy output. The treatment I_3 recorded the highest energy output and NER. However, it was at par with I_2. The higher energy output and NER under these treatments are due to higher grain and straw yields under these treatments. Baishya and Sharma (1990) [3] also reported similar results. Rainfed treatment recorded the lowest energy output and net return of energy due to the lowest grain and straw yield under the treatment.

Among the planting geometry, though there was not vast difference in energy consumption, the highest energy input was recorded in planting geometry 25 cm × 25 cm (S_3). This treatment also recorded the highest energy output and NER which were significantly higher than 30 cm × 30 cm (S_1), 30 cm × 25 cm (S_2) and 30 cm × 5-7 cm (S_4).

Energy efficiency

During both the years, irrigation at flower initiation and 50% flowering (I_2) recorded the highest energy productivity (111 and 93 g/MJ). However, it was at par with I_1 and I_3. During 2016-17, different irrigation treatments did not show any significant differences. However, I_2 recorded the highest value. During 2017-18, I_2 being at par with I_1 and I_3 recorded the highest energy use efficiency. In agricultural production system, law of diminishing return is invariably applicable. As such, it is not always possible to yield proportionate increase in output with increase in input energy. The lowest EP and EUE was recordeded under rainfed treatment. The highest specific energy (9.8 and 13.1 MJ/kg) was achieved with rainfed treatment (I_4) which was significantly higher than I_1, I_2 and I_3. It indicated higher amount of energy used to produce a unit of marketable product. Ansari *et al*. (2017) [2] and Kar *et al*. (2018) [5] found similar results.

Among the planting geometry, the highest energy productivity was recorded in planting geometry 25 cm × 25 cm (S_3) during both the year of study. However, it was at par with S_1 and S_2. Planting geometry 25 cm × 25 cm (S_3) also recorded the highest EUE and it was at par with S_2 during 2016-17. In 2017-18, it was at par with S_1 and S_2. The highest specific energy was, however, recorded under S_4 and it was at par with S_1 during 2016-17 and with S_1 and S_2 during 2017-18.

Table 1: Energy input, output and net return as influenced by different irrigation scheduling treatments

Treatment	Energy Input (MJ/ha)	Energy Output (MJ/ha)						Net Energy Return (MJ/ha)					
		Seed		Stover		Total		Seed		Stover		Total	
		2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Irrigation Schedule (I)													
I_1	15997	42925	35525	38013	33050	80938	68575	26928	19528	22016	17053	64941	52578
I_2	17335	48200	40300	42263	37063	90463	77363	30865	22965	24928	19728	73128	60028
I_3	18473	51075	42575	43725	38325	94800	80900	32602	24802	25252	19852	76327	62427
I_4	14459	37050	27600	34200	26225	71250	53825	22591	13141	19741	11766	56791	39366
SEm±	-	1685	1597	1456	1373	4033	3828	1429	1314	1228	1083	3774	3530
CD (P=0.05)	-	4123	3908	3562	3359	9869	9368	3496	3215	3005	2650	9236	8639
Planting geometry (S)													
S_1	16468	43775	35325	39813	32550	83588	67875	27307	18857	23345	16082	67120	51407
S_2	16588	45275	36875	41300	33963	86575	70838	28687	20287	24712	17375	69987	54250
S_3	16741	49175	39950	41588	36850	90763	76800	32434	23209	24847	20109	74022	60059
S_4	16668	41025	33875	35488	31250	76513	65125	24357	17207	18820	14582	59845	48457
SEm±	-	1826	1437	1708	1359	3443	2847	1715	1374	1368	1272	3306	2774
CD (P=0.05)	-	3768	2965	3526	2806	7106	5877	3539	2836	2824	2625	6823	5725

Table 2: Energy productivity, energy use efficiency and specific energy as influenced by different treatments

Treatment	Energy productivity (g/MJ)		Energy use efficiency (EUE)		Specific Energy (MJ/kg)	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Irrigation schedule (I)						
I_1	107	89	5.06	4.29	9.3	11.3
I_2	111	93	5.22	4.46	9.0	10.8
I_3	111	92	5.13	4.38	9.0	10.8
I_4	102	76	4.93	3.72	9.8	13.1
SEm±	3	5	0.22	0.20	0.3	0.6
CD (P=0.05)	8	12	NS	0.50	0.7	1.4
Planting geometry (S)						
S_1	106	86	5.08	4.12	9.4	11.7
S_2	109	89	5.22	4.27	9.2	11.2
S_3	117	95	5.42	4.59	8.5	10.5
S_4	98	81	4.59	3.91	10.2	12.3
SEm±	6	5	0.26	0.20	0.4	0.6
CD (P=0.05)	13	10	0.53	0.41	0.9	1.3

Conclusion

With mechanization of agriculture, to reduce the energy crisis, a rational use of inputs which maximizes the output is necessary. In the present study irrigation scheduled at flower initiation, 50% flowering and at siliqua development stage with planting geometry 25 cm x 25 cm gave the highest energy output.

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