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Economics and energetics in hybrid sunflower cultivation as influenced by irrigation and fertilizer management practices

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Abstract
The objective of the study was to assess economic feasibility and environmental sustainability in sunflower cultivation as influenced by irrigation and fertilization. A field experiment was conducted during the winter (November-March) of 2011-12 and 2012-2013 in farmer's field at Madandanga under Chakdaha block of Nadia district in West Bengal (23° 22.221'N latitude and 88°22.221'E longitude with an altitude of 12 m above mean sea level), under sub-humid subtropical climatic condition. The crop irrigated thrice ($I_{30/60/80}$) outperformed other crops which had reduced moisture (I_{30} and $I_{30/60}$) in respect of gross revenue (GR). Irrespective of irrigation levels, application of $N_{80}P_{40}K_{40}B_{1.5}S_{25}$ treatment paid the highest additional GR over RDF. The higher incremental cost-benefit ratio (ICBR) for 'Aditya' was observed with $N_{80}P_{40}K_{40}B_{1.5}$ at all irrigation levels. Estimated energy indices revealed that net energy gain (NEG) was the highest with the supply of $N_{80}P_{40}K_{40}B_{1.5}S_{25}$ at all irrigation levels. However, maximum values of energy ratio (ER) and energy productivity (EP) were recorded with $N_{80}P_{40}K_{40}B_{1.5}$ while total specific energy (SE) was higher with $N_{80}P_{40}K_{40}S_{25}$ for all irrigation levels. Recommended dose of fertilizer ($N_{80}P_{40}K_{40}$) was observed to be the most energy-intensive treatment with higher energy intensiveness (EI) values. The treatment $N_{80}P_{40}K_{40}VC_5$ was found to be the most energy-efficient treatment with lowest energy intensiveness (EI) values at all irrigation levels, closely followed by the $N_{80}P_{40}K_{40}B_{1.5}S_{25}$ treatment.

Keywords: Economic assessment, Energy budget, Fertilizer, Irrigation, Sunflower

INTRODUCTION

Adoption of site-specific nutrient and water management in sunflower cultivation is the true need of the hour to achieve highest productivity, profitability and energy-efficiency. Sunflower cultivation on rice-fallow lands during November to March is gaining popularity in West Bengal (Banerjee *et al*., 2014). This growing season (winter) of sunflower is characterized by cool-dry climate and very low or zero rainfall necessitating irrigation for good harvest. There are evidences to show that sunflower responds positively to judicious irrigation. In addition, under- or over-supply of irrigation water may affect growth, seed yield and oil quality of the crop. Moisture stress, especially at the most critical stages like seedling, flowering bud initiation and seed filling, results sharp decline in sunflower productivity (Bhattacharya, 2007).
Meeting the higher nutrient need of sunflower through site-specific and low-cost integrated nutrient management is the focus for reducing the cost and increasing the profitability besides maintaining soil fertility. Without careful management, the fertilizers can cause yield loss and lower the crop quality due to both under- and over-fertilization (Banerjee *et al*., 2017). To avoid the wastage of resources and to minimize the environment damage there is need to develop and demonstrate balanced use of chemical fertilizers. Apart from macronutrients (NPK), sulphur (S) and boron (B) play important roles in the production phenology of oilseed crops and these crops respond well to applied S and B (Karthikeyan and Shukla, 2008). Even the combined effects of S and B application on growth, seed yield and oil quality of sunflower plant remain unclear and merits further studies. Therefore, a suitable combination of major, secondary and micronutrients is by and large the most important single factor that could affects the yield and quality of sunflower soil. Organic manures besides supplying nutrients to the current crop, leaves substantial residual effect on the succeeding crop in the system and improves physical and biological properties of the soil. Singh *et al.* (2005) reported that application of 25 t FYM/ha

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recorded significantly higher biomass production and N uptake in sunflower over no FYM treatment. Therefore, a partial substitution/ or supplementation of chemical fertilizer with organic sources could be a viable alternative for maintenance of high organic matter status of soil resulting in higher and or sustainable crop productivity.

Understanding the energetics may provide additional information for identification of a better and efficient crop management practice (Ganajaxi *et al*., 2011). Agricultural output is proportional to the management of energy inputs such as irrigation and fertilizers. In order to boost up crop production, optimum use of these energy inputs is essential. While human labour and animal power are not enough for harnessing better crop yield, the use of machinery, irrigation and fertilizers can lead to increased productivity from limited land resources. Energy budgeting, the relationship between energy input and output, could be an important tool for intensification of sunflower cultivation in smallholder farmers' fields.

Economic analysis and energy budgeting of sunflower production have hardly been undertaken in the eastern Indo-Gangetic plains (IGPs) in a backdrop where risk and uncertainty associated with indiscriminate use of irrigation water and fertilizers by small and marginal farmers are notable (Banerjee *et al.*, 2017). The objective of this study was to estimate the profitability and energy productivity in sunflower cultivation.

MATERIALS AND METHODS

Location and growth conditions: A field experiment was conducted during the winter (November -March) of 2011-12 and 2012-2013 in farmer's field at Madandanga under Chakdaha block of Nadia district in West Bengal (23°22.221'N latitude and 88°22.221'E longitude with an altitude of 12 m above mean sea level), under sub-humid subtropical climatic condition.The soil of the experimental site is clay loam in texture,with a slightly acidic pH 6.89,and 0.42% organic carbon in the upper soil layer (0-30 cm).The available N, P and K recoveries were 175.4,27.5 and 108.08 kg/ ha,respectively, before initiation of the experiment.

Experimental design, treatments and crop management practices: The experiment was laid out in a split-plot design with combinations of three irrigation levels (I) as the main-plot factor and seven fertilizer treatments (F) as the subplot factor. Three irrigation levelswereI_1:One irrigation at 30 DAS, I_2:Two irrigations at 30 and 60 DAS, I_3:Three irrigations at 30, 60 and 80 DAS, and levels of fertilizer were F_1: 60-30-30 kg N-P_2O_5-K_2O/ha(FFP), F_2: 80-40-40 kg N-P_2O_5-K_2O/ha (RDF),F_3: F_2 + Boron @ 1.5 kg/ha, F_4: F_2 + Sulphur @ 25 kg/ ha, F_5:F_2 + Boron @ 1.5 kg/ ha + Sulphur @ 25 kg/ ha, F_6:F_2 + Farm yard manure @ 5 t/ haand F_7:F_2 + Vermicompost @ 5 t/ ha, respectively. The experimental design was replicated three times in 4 m×3m plots of each treatment.In last week of November, seeds were dibbled at 3-5 cm depth, with 2 seeds at each position. Spacing of 60 cm × 30 cm (55,555 plants/ha) was maintained by thinning and gap filling. The nutrients (NPK) were provided to the crop as per treatment details through urea (46% N), diammonium phosphate (18% N and 46% P_2O_5), muriate of potash (60% K_2O), zinc sulphate ($ZnSO_4$, $7H_2O$ with 11% S), Granubor® Nature (Disodium Tetraborate Pentahydrate; Granular with 15% B), farm yard manure (0.56% N, 0.24% P_2O_5 and 0.59% K_2O) and vermicompost (1.6% N, 0.98% P_2O_5 and 1.1% K_2O) respectively. All P, K, B and Zn fertilizers were applied to the soil prior to sowing in each plot. The N fertilizer was applied in three splits - 50% before sowing, 25% at 30 DAS and 25% at 45 DAS. FYM and vermicompost were surface broadcasted by hand during final land preparation (as basal). The crop was irrigated as per the treatment details during both the year of experimentation. Diesel operated water lifting pump (5 HP) was used for 15 hours to irrigate the crop with 50 ha-mm water under each irrigation. As a prophylactic measure, Neemazal -T/S (Azadirachtin 1% EC) was sprayed twice (at 35 and 42 DAS) @ 1 ml/litre of water. In addition, Pride (Acetamiprid 20% SP) was sprayed @ 3 g / 10 litres of water at 50 DAS for controlling white fly.The plants were cut at the base with the help of sickles at 120 DAS and then all the harvested mature capitulum containing seeds were sun dried for 2-3 days for easy removal of seeds.

Assessment of economic benefits: The common cost, treatment cost, total cost and economic assessment of hybrid sunflower cultivation were worked out on the basis of prevailing market prices of inputs and outputs during the respective crop seasons. The economic parameters like gross returns, net returns and incremental cost-benefit ratio (ICBR) were calculated as per the following formula (Sheoran *et al.*, 2013).

$$GR = Y_S \times P_S$$

$$NR = GR - TCP \quad ICBR = \frac{GR_T - GR_{RDF}}{TCP_T - TCP_{RDF}} \quad ..... (1)$$

Where, GR is gross return in ₹/ha; Y_S is seed yield in t/ha; P_S is minimum support price of seed in ₹/t; NR is net return in ₹/ha; TCP is total cost of production; ICBR = Incremental cost-benefit ratio; GR_T = Gross return of the treatment for which ICBR was calculated; GR_{RDF} = Gross return of the RDF treatment; TCP_T = Total cost of production with the treatment for which ICBR was calculated; TCP_{RDF} = Total cost of production of the RDF treatment.

Calculation of different energy indices: For estimation of energy budget in hybrid sunflower production system, the amounts of every input [tractor, cultivator, diesel, human, sunflower seed, water for irrigation, insecticide and sprayer] were considered for common energy input (Fig. 1). Fertilizer (N, P, K, S and B) and irrigation levels were considered for treatment energy input, while output energy was calculated considering the economic produce (grain and stalk). For estimating the energy value, quantity of different inputs and output were converted into energy terms by multiplying the respective energy equivalents (Table 1). The machine energy was calculated as per Devasenapathy *et al.* (2009) with minor change as follows.

$$ME = \frac{W}{L} \times T \times E \quad ....(2)$$

Where, ME is machine (tractor, disc harrow, water lifting pump and sprayer) energy in MJ/ha; W is weight of machine in kg; L is life span of machine; T is time of operation in hours; E is energy equivalent in MJ/ha.

The following energy indices were calculated for each treatment combinations as per the formula given by Banerjee *et al.* (2017).

$$NEG = E_0 - E_i \quad ....(3)$$

$$ER = \frac{E_0}{E_i} \quad SE = \frac{E_i}{Y_t} \quad EP = \frac{Y_t}{E_i} \quad EI = \frac{E_i}{TCP}$$

Where, NEG is net energy gain (MJ/ha); ER is energy ratio; SE is specific energy (MJ/kg); EP is energy productivity (kg/MJ); EI is energy intensiveness (MJ/₹); $E_o$is energy output (MJ/ha); E_i is energy input (MJ/ha); Y_t is biological yield (seed + stalk) (kg/ha); and TCPis total cost of production (₹/ha).

Source-wise input energy was categorized into direct and indirect as well as renewable and non-renewable forms (Mandal *et al.*, 2002) as depicted in Fig. 1. Per cent contribution of these sources of energy input was determined for evaluation of the best treatment in the present study (Fig. 2).

RESULTS AND DISCUSSION

Profitability of hybrid sunflower cultivation under different treatments: Economics is the foremost consideration that finally decides the adoption of any recommended practice at farming situations, and whether an agronomic management plan should be technically and economically viable to be sustainable (Ramesha *et al.*, 2011). In the present study, irrigation levels exerted positive effect on gross revenue (GR) and net return (NR) in hybrid sunflower cultivation (Table 2). The crop irrigated thrice ($I_{30/60/80}$) outperformed other crops which had reduced moisture (I_{30} and $I_{30/60}$) in respect of GR and NR. Total cost of cultivation differed marginally on account of irrigation omissions, but resulted in large differences in yield and net profit. Although the total cost involved in sunflower cultivation with three irrigations was more, but that was compensated by greater seed and stalk yield realized at this treatment. Irrespective of irrigation levels, combined application of B and S ($N_{80}P_{40}K_{40}B_{1.5}S_{25}$) paid the highest additional GR over RDF (Table 3). Higher productivity of the crop treated with $N_{80}P_{40}K_{40}B_{1.5}S_{25}$ was mainly responsible for higher return from this cultivar. Fertilizer levels exerted positive effect on incremental cost-benefit ratio (ICBR) in sunflower production. ICBR of hybrid sunflower cultivation was observed to decrease with increasing levels of irrigation up to three times. The higher ICBR for 'Aditya' was observed at $N_{80}P_{40}K_{40}B_{1.5}$ at all irrigation levels. Next best ICBR were recorded with the same variety receiving $N_{80}P_{40}K_{40}B_{1.5}S_{25}$ at I_{30} level. However, at

Table 1. Equivalent energy for different inputs and outputs for hybrid sunflower cultivation.

Particulars	Unit	Equivalent energy (MJ)	References
Input			
Adult man	Man-hour	1.96	Sadorsky (2006)
Adult Women	Women-hour	1.57	Mittal *et al.* (1985)
Diesel	Litre	56.31	Mittal *et al.* (1985)
Machinery/Electric motor	Kg	64.8	Jackson *et al.* (2011)
Farm machinery	Kg	62.7	Mittal *et al.* (1985)
N	Kg	60.6	Mittal *et al.* (1985)
P_2O_5	Kg	11.1	Mittal *et al.* (1985)
K_2O	Kg	6.7	Mittal *et al.* (1985)
$ZnSO_4$	Kg	20.9	Devasenapathy *et al.* (2009)
Granubor	Kg	10.0	Devasenapathy *et al.* (2009)
Farm yard manure	Kg (dry mass)	0.3	Devasenapathy *et al.* (2009)
Vermicompost	Kg (dry mass)	0.3	Devasenapathy *et al.* (2009)
Superior chemicals (herbicide and insecticide)	Kg	120.0	Mittal *et al.* (1985)
Sunflower seed	Kg	25.0	Devasenapathy *et al.* (2009)
Output			
Sunflower seed	Kg (dry mass)	25.0	Devasenapathy *et al.* (2009)
Stalk	Kg (dry mass)	18.0	Devasenapathy *et al.* (2009)

MJ, Mega-Joule

Table 2. Economic assessment of hybrid sunflower cultivation/hectare (mean data of two years).

Treatment combinations	Common cost (₹) (A)	Treatment cost (₹/ha)		Total cost (₹) (A+B+C)	Price of production (₹/ha)				Financial benefit (₹/ha)	
		Irrigation (B)	Fertilizer (C)		Seed yield (t/ha)	Price* (₹) (A)	Stalk yield (t/ha)	Price (₹) (B)	Gross return (₹/ha) (A + B)	Net return (₹/ha)
$I_{30} \times N_{60}P_{30}K_{30}$	29760	2284	4687	36731	0.975	53625	3.185	6370	59995	23264
$\times N_{80}P_{40}K_{40}$	29760	2284	5692	37736	1.195	65725	3.640	7280	73005	35269
$\times N_{80}P_{40}K_{40}B_{1.5}$	29760	2284	7042	39086	1.340	73700	4.440	8880	82580	43494
$\times N_{80}P_{40}K_{40}S_{25}$	29760	2284	31829	63873	1.365	75075	4.595	9190	84265	20392
$\times N_{80}P_{40}K_{40}B_{1.5}S_{25}$	29760	2284	33179	65223	1.470	80850	5.165	10330	91180	25957
$\times N_{80}P_{40}K_{40}FYM_5$	29760	2284	13192	45236	1.250	68750	3.715	7430	76180	30944
$\times N_{80}P_{40}K_{40}VC_5$	29760	2284	30692	62736	1.270	69850	4.050	8100	77950	15214
$I_{30/60} \times N_{60}P_{30}K_{30}$	29760	4568	4687	39015	1.285	70675	3.925	7850	78525	39510
$\times N_{80}P_{40}K_{40}$	29760	4568	5692	40020	1.375	75625	4.750	9500	85125	45105
$\times N_{80}P_{40}K_{40}B_{1.5}$	29760	4568	7042	41370	1.615	88825	5.520	11040	99865	58495
$\times N_{80}P_{40}K_{40}S_{25}$	29760	4568	31829	66157	1.710	94050	5.665	11330	105380	39223
$\times N_{80}P_{40}K_{40}B_{1.5}S_{25}$	29760	4568	33179	67507	1.810	99550	5.925	11850	111400	43893
$\times N_{80}P_{40}K_{40}FYM_5$	29760	4568	13192	47520	1.535	84425	5.200	10400	94825	47305
$\times N_{80}P_{40}K_{40}VC_5$	29760	4568	30692	65020	1.585	87175	5.415	10830	98005	32985
$I_{30/60/80} \times N_{60}P_{30}K_{30}$	29760	6852	4687	41299	1.555	85525	5.990	11980	97505	56206
$\times N_{80}P_{40}K_{40}$	29760	6852	5692	42304	1.690	92950	6.710	13420	106370	64066
$\times N_{80}P_{40}K_{40}B_{1.5}$	29760	6852	7042	43654	1.950	107250	7.800	15600	122850	79196
$\times N_{80}P_{40}K_{40}S_{25}$	29760	6852	31829	68441	1.975	108625	7.990	15980	124605	56164
$\times N_{80}P_{40}K_{40}B_{1.5}S_{25}$	29760	6852	33179	69791	1.980	108900	8.325	16650	125550	55759
$\times N_{80}P_{40}K_{40}FYM_5$	29760	6852	13192	49804	1.825	100375	7.210	14420	114795	64991
$\times N_{80}P_{40}K_{40}VC_5$	29760	6852	30692	67304	1.835	100925	7.410	14820	115745	48441

Subscript digits signify respective timing of irrigation in DAS, dose of inorganic nutrients in kg/ha and organic manures in t/ha; * Selling price of sunflower seed ₹ 55 /- per kg; # Selling price of sunflower stalk ₹ 2 /- per kg

Table 3. Annual financial benefits from hybrid sunflower (cv. Aditya) production as determined from different treatment combinations (mean data of 2 years).

Treatment combinations	Additional yield over RDF (t/ha)	Additional cost over RDF (₹/ha)	Additional gross return over RDF (₹/ha)	ICBR*
I_{30} × $N_{60}P_{30}K_{30}$ (FFP)	NA	NA	NA	NA
× $N_{80}P_{40}K_{40}$ (RDF)	-	-	-	-
× $N_{80}P_{40}K_{40}B_{1.5}$	0.14	1350	9575	7.09
× $N_{80}P_{40}K_{40}S_{25}$	0.17	26137	11260	0.43
× $N_{80}P_{40}K_{40}B_{1.5}S_{25}$	0.27	27487	18175	0.66
× $N_{80}P_{40}K_{40}FYM_5$	0.05	7500	3175	0.42
× $N_{80}P_{40}K_{40}VC_5$	0.07	25000	4945	0.20
$I_{30/60}$ × $N_{60}P_{30}K_{30}$ (FFP)	NA	NA	NA	NA
× $N_{80}P_{40}K_{40}$ (RDF)	-	-	-	-
× $N_{80}P_{40}K_{40}B_{1.5}$	0.24	1350	14740	10.92
× $N_{80}P_{40}K_{40}S_{25}$	0.33	26137	20255	0.77
× $N_{80}P_{40}K_{40}B_{1.5}S_{25}$	0.43	27487	26275	0.96
× $N_{80}P_{40}K_{40}FYM_5$	0.16	7500	9700	1.29
× $N_{80}P_{40}K_{40}VC_5$	0.20	25000	12880	0.52
$I_{30/60/80}$ × $N_{60}P_{30}K_{30}$ (FFP)	NA	NA	NA	NA
× $N_{80}P_{40}K_{40}$ (RDF)	-	-	-	-
× $N_{80}P_{40}K_{40}B_{1.5}$	0.26	1350	16480	12.21
× $N_{80}P_{40}K_{40}S_{25}$	0.28	26137	18235	0.70
× $N_{80}P_{40}K_{40}B_{1.5}S_{25}$	0.29	27487	19180	0.70
× $N_{80}P_{40}K_{40}FYM_5$	0.13	7500	8425	1.12
× $N_{80}P_{40}K_{40}VC_5$	0.15	25000	9375	0.38

FFP, Farmer's fertilizer practice; RDF, Recommended dose of fertilizer; NA, Not applicable; * Incremental Cost-Benefit Ratio; Subscript digits signify respective timing of irrigation in DAS, dose of inorganic nutrients in kg/ha and organic manures in t/ha.

Table 4. Energy budgeting in hybrid sunflower (cv. Aditya) cultivation with different treatment combinations (mean data of 2 years).

Treatment combinations	Energy Input (MJ/ha)				*Energy output (MJ/ha)		
	Common (A)	Treatment		Total (A+B+C)	Seed (Y)	Stalk (Z)	Total (Y+Z)
		Irrigation (B)	Fertilizer (C)				
I_{30} × $N_{60}P_{30}K_{30}$ (FFP)	3560	550	4170	8280	24375	57330	81705
× $N_{80}P_{40}K_{40}$ (RDF)	3560	550	5560	9670	29875	65520	95395
× $N_{80}P_{40}K_{40}B_{1.5}$	3560	550	5660	9770	33500	79920	113420
× $N_{80}P_{40}K_{40}S_{25}$	3560	550	10310	14420	34125	82710	116835
× $N_{80}P_{40}K_{40}B_{1.5}S_{25}$	3560	550	10410	14520	36750	92970	129720
× $N_{80}P_{40}K_{40}FYM_5$	3560	550	7060	11170	31250	66870	98120
× $N_{80}P_{40}K_{40}VC_5$	3560	550	7060	11170	31750	72900	104650
$I_{30/60}$ × $N_{60}P_{30}K_{30}$ (FFP)	3560	1110	4170	8840	32125	70650	102775
× $N_{80}P_{40}K_{40}$ (RDF)	3560	1110	5560	10230	34375	85500	119875
× $N_{80}P_{40}K_{40}B_{1.5}$	3560	1110	5660	10330	40375	99360	139735
× $N_{80}P_{40}K_{40}S_{25}$	3560	1110	10310	14980	42750	101970	144720
× $N_{80}P_{40}K_{40}B_{1.5}S_{25}$	3560	1110	10410	15080	45250	106650	151900
× $N_{80}P_{40}K_{40}FYM_5$	3560	1110	7060	11730	38375	93600	131975
× $N_{80}P_{40}K_{40}VC_5$	3560	1110	7060	11730	39625	97470	137095
$I_{30/60/80}$ × $N_{60}P_{30}K_{30}$ (FFP)	3560	1650	4170	9380	38875	107820	146695
× $N_{80}P_{40}K_{40}$ (RDF)	3560	1650	5560	10770	42250	120780	163030
× $N_{80}P_{40}K_{40}B_{1.5}$	3560	1650	5660	10870	48750	140400	189150
× $N_{80}P_{40}K_{40}S_{25}$	3560	1650	10310	15520	49375	143820	193195
× $N_{80}P_{40}K_{40}B_{1.5}S_{25}$	3560	1650	10410	15620	49500	149850	199350
× $N_{80}P_{40}K_{40}FYM_5$	3560	1650	7060	12270	45625	129780	175405
× $N_{80}P_{40}K_{40}VC_5$	3560	1650	7060	12270	45875	133380	179255

FFP, Farmer's fertilizer practice; RDF, Recommended dose of fertilizer; MJ, Mega-Joule; Subscript digits signify respective timing of irrigation in DAS, dose of inorganic nutrients in kg/ha and organic manures in t/ha; * Energy output (seed/stalk) = Seed/stalk yield (kg) × equivalent energy (25 and 18 MJ/kg dry mass of seed and stalk, respectively).

Table 5. Energy indices in hybrid sunflower (cv. Aditya) cultivation under different treatment combinations (mean data of 2 years).

Treatment combinations	Net energy gain (GJ/ha)	Energy ratio	Specific energy (MJ/kg)			Energy productivity (kg/MJ)			Energy intensiveness (MJ/₹)
			Seed (A)	Stalk (B)	Total (A+B)	Seed (Y)	Stalk (Z)	Total (Y+Z)	
I_{30} × $N_{60}P_{30}K_{30}$ (FFP)	73.4	9.87	8.49	1.84	10.33	0.118	0.542	0.660	0.225
× $N_{80}P_{40}K_{40}$ (RDF)	85.7	9.86	8.09	2.08	10.17	0.124	0.480	0.604	0.256
× $N_{80}P_{40}K_{40}B_{1.5}$	103.7	11.61	7.29	1.89	9.18	0.137	0.528	0.665	0.250
× $N_{80}P_{40}K_{40}S_{25}$	102.4	8.10	10.56	2.88	13.44	0.095	0.347	0.442	0.226
× $N_{80}P_{40}K_{40}B_{1.5}S_{25}$	115.2	8.93	9.88	2.69	12.57	0.101	0.372	0.473	0.223
× $N_{80}P_{40}K_{40}FYM_5$	87.0	8.78	8.94	1.89	10.83	0.112	0.530	0.642	0.247
× $N_{80}P_{40}K_{40}VC_5$	93.5	9.37	8.80	2.03	10.83	0.114	0.491	0.605	0.178
$I_{30/60}$ × $N_{60}P_{30}K_{30}$ (FFP)	93.9	11.63	6.88	2.00	8.88	0.145	0.501	0.646	0.227
× $N_{80}P_{40}K_{40}$ (RDF)	109.6	11.72	7.44	1.93	9.37	0.134	0.518	0.652	0.256
× $N_{80}P_{40}K_{40}B_{1.5}$	129.4	13.53	6.40	1.88	8.28	0.156	0.531	0.687	0.250
× $N_{80}P_{40}K_{40}S_{25}$	129.7	9.66	8.76	2.75	11.51	0.114	0.364	0.478	0.226
× $N_{80}P_{40}K_{40}B_{1.5}S_{25}$	136.8	10.07	8.33	3.16	11.49	0.120	0.316	0.436	0.223
× $N_{80}P_{40}K_{40}FYM_5$	120.2	11.25	7.64	2.11	9.75	0.131	0.473	0.604	0.247
× $N_{80}P_{40}K_{40}VC_5$	125.4	11.69	7.40	1.98	9.38	0.135	0.506	0.641	0.180
$I_{30/60/80}$ × $N_{60}P_{30}K_{30}$ (FFP)	137.3	15.64	6.03	2.09	8.12	0.166	0.479	0.645	0.227
× $N_{80}P_{40}K_{40}$ (RDF)	152.3	15.14	6.37	2.27	8.64	0.157	0.441	0.598	0.255
× $N_{80}P_{40}K_{40}B_{1.5}$	178.3	17.40	5.57	1.86	7.43	0.179	0.538	0.717	0.249
× $N_{80}P_{40}K_{40}S_{25}$	177.7	12.45	7.86	2.88	10.74	0.127	0.347	0.474	0.227
× $N_{80}P_{40}K_{40}B_{1.5}S_{25}$	183.7	12.76	7.89	2.64	10.53	0.127	0.378	0.505	0.224
× $N_{80}P_{40}K_{40}FYM_5$	163.1	14.30	6.72	2.00	8.72	0.149	0.499	0.648	0.246
× $N_{80}P_{40}K_{40}VC_5$	167.0	14.61	6.69	2.25	8.94	0.150	0.444	0.594	0.182

FFP, Farmer's fertilizer practice; RDF, Recommended dose of fertilizer; GJ, Giga-Joule; MJ, Mega-Joule; Subscript digits signify respective timing of irrigation in DAS, dose of inorganic nutrients in kg/ha and organic manures in t/ha.

$I_{30/60}$ and $I_{30/60/80}$ levels, the treatment $N_{80}P_{40}K_{40}FYM_5$ recorded second best ICBR closely followed by $N_{80}P_{40}K_{40}B_{1.5}S_{25}$.The negative response in GR and ICBR was recorded in plots treated with FFP ($N_{60}P_{30}K_{30}$) that might be due to poor growth and low productivity of the potato (Baishya *et al*., 2013). These results are in partial agreement with the finding of Love *et al.* (2005), which reported that gross returns were relatively low with FFP, and increased to a highest level at balanced fertilizer rate.

Input and output energy in hybrid sunflower cultivation: Energy used for raising sunflower cultivar (cv. Aditya) was computed to augment energy budgeting. The energy inputs (E_i) against each field operation were classified as direct energy (that release the energy directly) and indirect energy (those do not release energy directly but release it by conversion process) (Fig. 1). Both direct and indirect sources of energy were grouped into renewable (direct in nature but can be subsequently replenished) and non-renewable sources (not replenished in due course of time). In the present study, the direct sources of energy include human, animal and diesel, of which human and animal were categorized as renewable

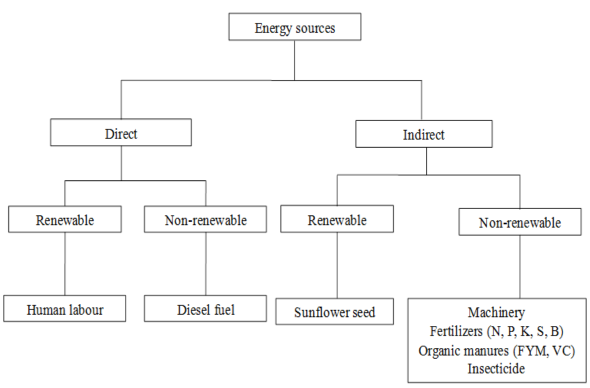

Fig. 1. *Flow chart on different sources of energy inputs.*

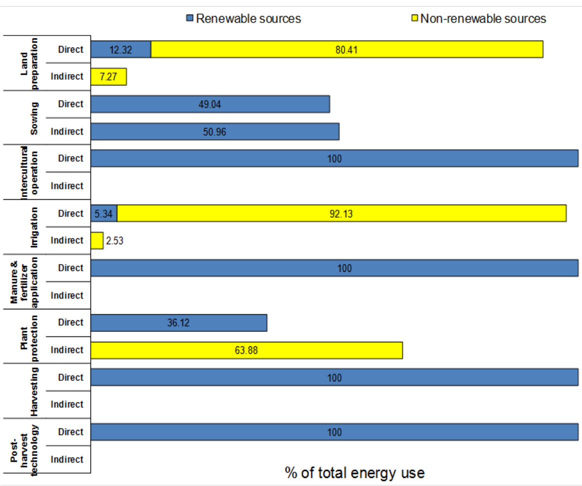

Fig. 2.*Operation wise energy use in hybrid sunflower cultivation.*

direct energy sources, while the only non-renewable direct energy source was diesel. On the other hand, the indirect sources of energy include seed, chemical fertilizers and machinery, of which only seed was categorized as renewable indirect energy source, while the non-renewable indirect energy sources were chemical fertilizer and machinery. For most of the field operations, the involvement of direct sources of energy was greater than that of indirect sources, while the trend was reverse for sowing and plant protection operations (Fig. 2).

More specifically, the per cent sharing of direct energy was 100 (total renewable source) for intercultural operations, manures and fertilizer application, harvesting and post-harvest technology (Fig. 2). But in case of other field operations like land preparation and irrigation, the major energy input was from direct non-renewable resources (80.41 and 92.13%, respectively). Involvement of indirect energy sources was greater than direct sources for sowing and plant protection. More specifically, 63.88% share of indirect energy in plant protection operation was from non-renewable sources. On the other hand, the major share of indirect energy in sowing operation was from renewable sources (50.96%).

In the present study, energy output (E_o) increased with increasing level of irrigation for each fertilizer level. The supply of $N_{80}P_{40}K_{40}B_{1.5}S_{25}$ recorded better energy output at all levels of irrigation (Table 4). This trend is similar to that of seed yield since the E_o is dependent on economic part of the groundnut (Ganajaxi *et al.*, 2011).

Energy budgeting: Estimated energy indices (Table 5) revealed that both net energy gain (NEG) and energy ratio (ER) increased with increasing level of irrigation for each fertilizer level while the trend was just reverse for specific energy (SE). NEG was the highest with the supply of $N_{80}P_{40}K_{40}B_{1.5}S_{25}$ at all irrigation levels. However, maximum values of ER and energy productivity (EP) were recorded with RDF + B application ($N_{80}P_{40}K_{40}B_{1.5}$) while total SE was maximum with RDF + S application ($N_{80}P_{40}K_{40}S_{25}$) for all irrigation levels. Recommended dose of fertilizer ($N_{80}P_{40}K_{40}$) was observed to be the most energy-intensive treatment with higher energy intensiveness (EI) values. Vermicompost application along with RDF ($N_{80}P_{40}K_{40}VC_5$) was found to be the most energy-efficient treatment with lowest energy intensiveness (EI) values at all irrigation levels, closely followed by the combined application of B and S ($N_{80}P_{40}K_{40}B_{1.5}S_{25}$). Therefore, balanced fertilization with proper source resulted energy-efficient sunflower production system. According to present study, ER and EP exhibited phenomenal increase with B only in addition to RDF. This is due to lesser inputs used at this level as compared to higher fertilizer levels, which corroborates with earlier study of Banerjee *et al.* (2017), who opined that higher energy input resulted in lower energy ratio and energy productivity in potato. According to Tzanakakis*et al.* (2012), agronomic practices in *Acacia cyanophylla* with greater differences between energy output and input leading to higher net energy gain have potential to be used as a bio-energy management indicating its environmental and economic sustainability. Thus, as the cultivar showed higher response to combined application of B and S ($N_{80}P_{40}K_{40}B_{1.5}S_{25}$) with respect to seed yield, the present level of energy input use (other than fertilizers sources) should be substantially reduced by using energy-efficient machinery (not worn-out tractors), adopting some conservation measures (like mulching), less pressurized irrigation system and more use of diesel in place of electricity.

Conclusion

This study emphasizes the urgency to optimize fertilization practice of sunflower to ensure an energy-efficient and profitable production system.In this research that was carried out in winter 2011-12 and 2012-13 in humid-tropical climate of West Bengal, conclusions can be stated as follows:The $N_{80}P_{40}K_{40}B_{1.5}S_{25}$ treatment recorded highest gross return followed by $N_{80}P_{40}K_{40}S_{25}$ and $N_{80}P_{40}K_{40}B_{1.5}$ treatments, irrespective of irrigation frequencies. The $N_{80}P_{40}K_{40}B_{1.5}$ treatment recorded highest ICBR values at all irrigation levels followed by $N_{80}P_{40}K_{40}FYM_5$ and $N_{80}P_{40}K_{40}B_{1.5}S_{25}$ treatment. The $N_{80}P_{40}K_{40}B_{1.5}S_{25}$ treated crops exhibited highest energy output. This strategy makes the best use of NPK fertilizers along with B and S, minimizes the quantity and investment in inorganic fertilizer required by sunflower growers. Better understanding of energetics may provide supplementary information for standardization of a energy-efficient sunflower management practice, and thereby reduce over-application of NPK fertilizer to sunflower.

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