



Energy Analysis for Cultivation of Sugarcane: A Case Study in Narsinghpur (M. P.), India

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AK and AP designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author AKS guided the analyses of the study. Author AKS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The purpose of this study was to determine the commercial or non-commercial energy sources which were used for the cultivation of sugarcane in the selected area of study, Narsinghpur (Madhya Pradesh), India.

The use of commercial and non-commercial energy was found 143947.43 MJ/ha and its ratio with non-commercial energy was 18.35 during the last survey of the study area during 2013-14. The productivity energy was found during the study period 0.35 kg/MJ. Due to better management of energy inputs the output-input energy ratio enhanced by 6.86% during the study period. Energy inputs are carried out and the research finding shows that there exists a positive and direct correlation between yield and tillage, irrigation and total energy at 1 per cent level of significance. It is also seen that the contribution of energy through diesel, fertilizers and electricity were significant at 1 per cent level of significance.

The result of the study of commercial and non-commercial energy sources were used in cultivation

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of sugarcane, we found the use of electric energy (75191.32 MJ/ha) was the highest energy consuming source from commercial energy sources and the use of human energy (5819.21 MJ/ha) was the highest energy consuming source from non-commercial energy sources.

Keywords: Sugarcane; commercial energy source; non-commercial energy source; cultivation; Narsinghpur.

1. INTRODUCTION

Energy is Life. Energy comes from food and thus from agriculture. Agriculture depends on energy input. Energy capacity of activity. Survival, convenience and comfort of human being depend on how best the energy is captured, transformed and utilized. "To identify the energetic relationships of agricultural systems and to be understood" we must be able to correctly identify and measure the flow of energy in the system. We call such activities as agricultural energetics. Although contemporary, energy-intensive agricultural systems are highly productive, their sustainability is questionable because rapid population growth necessitates continued increases in the use of crop to land and water resources and fossil energy resources that are essential for supplying fertilizers, pesticides, irrigation, and mechanization are non-renewable [1,2].

Economic growth is desirable for developing countries, and increased energy demand is not always a straight forward linear one. For example, under present conditions, 7% increase in India's (GDP) would impose an increased demand of 11% on its energy sector. In this context, the ratio of energy demand to GDP is a useful indicator. A high ratio reflects energy dependence and a strong influence of energy GDP growth. The developed countries, by focusing energy efficiency and lower energy-intensive routes, maintain their energy to GDP ratios at values of less than one. The ratios for developing countries are much higher [3].

The present level of power consumption in Indian agriculture is 1, 63,300 MW. The power availability for production agriculture in India is 1.50 kW/ha and lies higher requirement in Punjab which is about 3.25 kW/ha [4]. In comparison of above Japan is the highest energy consuming country, where the energy input to agriculture production is 13 kW/ha. The per capita energy consumption is low for India as compared to developed countries. It is just 20% of the world average. The per capita consumption is likely to grow in India with growth

in economy thus increasing the energy demand [4,1,2].

Agricultural production can be increased, by bringing the additional land area under cultivation, and by increasing the cropping intensity. Productivity can be increased by increasing the production per unit area of land, which in turn also increases the total production [5]. In India, there is little additional land available for agriculture. The increase in cropping intensity require an additional supply of energy for irrigation as well as for timely tillage and harvesting. Increase in productivity also requires additional mechanical power. A substantial increase in the yields of important cereals and coarse grains were made possible by the introduction of high yielding varieties and increase of area under irrigation. But this success was achieved mainly with the help of fertilizers and wider utilization of mechanical and electrical power in farming, particularly in Punjab, Haryana and Western Uttar Pradesh. [5].

Sugarcane is an important commercial crop and cultivated in about 75 countries. The leading countries are Brazil, India, China, Thailand and Pakistan. Brazil country occupies the area i.e. 5.343 million ha. of sugarcane with 386.2 million-ton production in year 2013-2014 [6]. India occupies the second rank in production of sugarcane in the world, it contributing nearly 20.4% area and 18.60% production. The area under sugarcane in India is 4.608 million ha. and production of 289.6 million tons with the productivity of 62.8 tons/ha. The major sugarcane growing states are Uttar Pradesh, Maharashtra, Andhra Pradesh, Tamil Nadu and Madhya Pradesh in India. Among the states, Uttar Pradesh occupied maximum area (22.77 lakh ha.) under sugarcane with production of 135.64 million tons and productivity 59.60 tons/ha., which covers 41% area of sugarcane in India [2,3].

In Madhya Pradesh the area under sugarcane was 0.88 lakh ha, and production 4.22 million tons with productivity of 47.80 tons/ ha. (2013-2014) Narsinghpur district is one of the major

sugarcane growing districts in the state. The area under sugarcane was 23562 ha., with production of 125.2 thousand tones, which covers 18.3% area and 20.5% production in the states during the year 2013-2014 [6].

1.1 Major Sugarcane Growing States

Sugarcane is grown in various states in subtropical and tropical regions of the country. Main sugarcane growing states are:

1.1.1 Sub Tropical

Uttar Pradesh, Uttarakhand, Haryana, Punjab, Bihar with an annual rainfall of 180 to 2000 mm. The climate ranges from humid, moist sub-humid and dry sub-humid to cold arid, semiarid and arid.

1.1.2 Tropical region

Karnataka, Tamil Nadu, Maharashtra, Andhra Pradesh, Gujarat, Madhya Pradesh with an annual rainfall of 602 to 3640 mm having moist to dry sub-humid and semi-arid to dry semi-arid climates [7].

1.2 Important Regions/ Zones for Sugarcane Cultivation in India

Broadly there are two distinct agro-climatic regions of sugarcane cultivation in India, viz., tropical and subtropical. Tropical region shared about 45% and 55% of the total sugarcane area and production in the country, respectively. The sub-tropical region accounted for about 55% and 45% of total area and production of sugarcane, respectively [8].

1.2.1 Tropical sugarcane region

The tropical sugarcane region includes the states of Maharashtra, Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Madhya Pradesh, Goa, Pondicherry and Kerala. The coastal areas of A.P. and Tamil Nadu have high sugarcane productivity. Floods, water logging and diseases such as red rot are the main problems. In the tropical region climatic conditions are more favourable for its growth. It is cultivated with better package of practices and higher irrigation levels. The growing season is long with more equitable and favourable conditions without serious weather extremes. Being a tropical country the agro-climatic conditions of tropical India favour higher sugarcane and sugar yields.

The tropical region contributes about 55% to the total cane production in the country. The average cane yields of the major states of the region including Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh and Gujarat is around 80 tons/ha. Maharashtra and the adjoining area of Karnataka, Gujarat and A.P. record higher sugar recovery. Long hours of sunshine, cool nights with clear skies and the latitudinal position of this area are highly favourable for sugar accumulation. Moisture stress during the early part of the cane growths mostly during March to June is a major constraint in the state of Maharashtra & other part of region lacking a perennial source of irrigation [8-10].

1.2.2 Sub-tropical sugarcane region

Around 55% of total cane area in the country is in the sub-tropics. U.P, Bihar, Haryana and Punjab comes under this region. Extremes of climate are the characteristic feature of this region. During April to June, the weather is very hot and dry. July to October is rainy season accounting for most of the rainfall from South-West monsoon rains. December and January are the very cold months' temperature touching sub-zero levels in many places. November to March are cool months with clear sky. The cane yield is lower in the subtropics due to various reasons viz., short growing season, high-temperature disparity besides other factors like moisture stress, pest and disease problem, floods and water logging and very poor ratoons. The average yield of the four major states (U.P, Bihar, Punjab and Haryana) is around 60 tons/ha. However, there is considerable potential to be exploited [8,11,12].

The energy consumption in the production of sugarcane is highest as compared to many other crops such as potato, maize, wheat, rice, sorghum etc. Sugarcane is labour intensive requiring about 3300 man-hrs per hectare for different operations. Considering the present trend of availability of labour for sugarcane production, it has been experienced that the use of modern machinery is inevitable. Use of machinery helps in labour saving and timelines of operations, reduces drudgery, helps in improving quality of work, reduces cost of operation and ensures effective utilization of resources [7,8].

The objective of this study is to calculate the commercial and non-commercial energy used for cultivation of sugarcane crop in the selected area of study (Narsinghpur).

Table-1. All India state wise area coverage and yield estimate of sugarcane during 2013-2016

Name of state	2013-14			2014-15			2015-16		
	Area (000ha)	Production (000 t)	Yield (t/ha)	Area (000ha)	Production (000 t)	Yield (t/ha)	Area (000ha)	Production (000t)	Yield (t/ha)
Madhya Pradesh	73	3173	43.47	111	4567	41.14	73	3343	45.79
Andhra Pradesh	192	15385	80.13	177	13150	74.29	157	12460	79.36
Tamil Nadu	313	32454	103.69	263	24463	93.02	263	27615	105.0
Gujrat	174	12550	72.13	204	14060	68.92	185	13040	70.49
Punjab	89	6675	75.00	94	7039	74.88	99	7131	72.03
Uttar Pradesh	2228	134689	60.45	2228	138481	62.15	2116	133203	62.95
India	4993	352141	70.53	5144	359330	69.85	4918	341425	69.42

Source: Indian institute of sugarcane research institute Lucknow/database, 2017.

2. MATERIALS AND METHODS

This section deals with the optimization of commercial like, petrol, diesel, electricity, chemical, fertilizer, machinery etc and non-commercial energy sources like, human, animal, fuel wood, agricultural waste and farm yard manure (FYM), which were used for cultivation of sugarcane in the selected area of study, and the following section will be completed by selection of villages and farmers, categorization of farmers/farms and method employed for data collection from farmers. The 10 farmers were randomly selected from the area of study and the data were collected from farmers through face to face questionnaire/survey and then analysis or optimization of commercial and non-commercial energy inputs to attain the objectives of the study.

2.1 Commercial Sources of Energy

Commercial sources of energy are those, which are commercially produced. For example, petrol, diesel, electricity, chemical, fertilizer, machinery etc.

2.2 Non-commercial Sources of Energy

Direct and indirect energy of sources, which are not commercially produced, are called non-commercially sources of energy. For example, human, animal, fuel wood, agricultural waste and farmyard manure (FYM).

2.3 Energy Calculation for Field Operations

The energy used in the particular field operation was calculated as sum of human, animal, mechanical and electrical energy consumed. Energy consumption from both in terms of commercial and non-commercial energy sources

(direct & in-direct) was also quantified for sugarcane crop and cropping pattern.

2.3.1 Electric power

The electrical input for an electric motor was determined from the following formula:

$$E = RHP \times 0.746 \times \text{Hours of use} \times Ef \quad (1)$$

Where:

- E = Electricity input (kWh)
- RHP = Rated power of electric motor, hp
- Ef = Efficiency of the system (may be taken as 0.80)

The electric input was recorded through energy meter in terms of units

i.e. 1 unit = 1kWh [7].

2.3.2 Man power

Manpower is one of the most important power sources on the farm. Energy equivalent for an adult man is taken as 1.96 MJ/man-h. The wages of a farm labour are taken as prevailing rate in a particular locality.

$$A_1 \leq \sum_{i=1}^n h_i X_i \leq A_2 \quad (2)$$

Where,

- h_i = Human energy level for activity i , MJ/ha;
- A_1 = Lower bound on human energy available per activity; and
- A_2 = Upper bound on human energy available per activity.

2.3.3 Animal power

Animal power is the major power source on the farm to perform the activities Like tillage and sowing, interculture, transportation of farm

produce, seeds, fertilizers and even in threshing. The energy input of a pair of bullocks (having a body weight of about 450 kg) was assumed to be 10.10 MJ/pair-h.

$$A_{in} \leq \sum_{i=1}^n a_{ni} X_i \leq A_{2n} \quad (3)$$

Where,

- a_{ni} = Animal energy level for activity i , MJ/ha;
- A_{in} = Lower bound on animal energy available per activity; and
- A_{2n} = Upper bound on animal energy available per activity.

2.3.4 Machinery/equipment energy

Calculation of energy through machinery/equipment is done by given coefficient (numerical).

$$M_1 \leq \sum_{i=1}^n m_i X_i \leq M_2 \quad (4)$$

Where,

- m_i = Machine energy level for activity i , MJ/ha;

- M_1 = Lower bound on machine energy available per activity; and
- M_2 = Upper bound on machine energy available per activity.

2.3.5 Chemical energy

$$C_1 \leq \sum_{i=1}^n c_i X_i \leq C_2 \quad (5)$$

Where,

- c_i = Agro-chemical energy level for activity i , MJ/ha;
- C_1 = Lower bound on agro-chemical energy available per activity;
- C_2 = Upper bound on agro-chemical energy available per activity.

2.3.6 Total energy

$$T_1 \leq \sum_{i=1}^n t_i X_i \leq T_2 \quad (6)$$

Where,

- t_i = Total energy consumed by activity i , in MJ/ha;
- T_1 = Lower bound on total energy available per activity in MJ/ha;
- T_2 = Upper bound on total energy available per activity in MJ/ha.

Table 2. Equivalent coefficient for various sources of energy used for energy calculations

Items	Energy equivalent MJ/Unit
1. Human labour	
➤ Male	1.96 MJ/ man hr
➤ Female	1.57 MJ/ female hr
2. Bullock with a body weight 350-450 kg/ bullock	10.10 MJ/pair
3. Diesel	56.31 J/lit
4. Machinery*	
➤ Prime mover other than electric motor including self	64.8 MJ/kg
➤ Farm machinery other than propelled ones	62.7 MJ/kg
5. Electric motor	11.93 MJ/kWh
➤ Irrigation	45.88 MJ/hr
➤ Threshing	68.82 MJ/hr
6. Tractor	
➤ Ploughing	197 MJ/hr
➤ Threshing	169 MJ/hr
7. Fertilizer	
➤ Nitrogen	60.0 MJ/kg
➤ Phosphorus	11.1 MJ/kg
➤ Potash	6.7 MJ/kg
8. Farm Yard Manure	0.3 MJ/kg
9. Chemicals	
➤ Superior, needing dilution	120 MJ/lit
➤ Inferior, not needing dilution	10 MJ/kg
10. Crop	
➤ Sugarcane	5.3 MJ/kg

3. RESULTS AND DISCUSSION

This study dealt with the results obtained from the field studies and its interpretation of the sugarcane cultivation in the Narsinghpur (Madhya Pradesh). This included with the demographic details. Under this study, the following aspects were studied such as, energy use pattern through commercial and non-commercial sources, farm machinery and power availability, optimization of energy use and prediction of energy requirement from different sources for required yield level of sugarcane for a selected area of the study, Narsinghpur (Madhya Pradesh).

3.1 Commercial Energy Sources (MJ/ha)

During the study of commercial energy sources from the selected area of Narsinghpur (Madhya Pradesh). Shown in Fig. 1 we found that the farmers were used the diesel energy (15211.46 MJ/ha), electricity energy (75191.32 MJ/ha), chemical energy (204.10 MJ/ha), fertilizer energy (11836.4 MJ/ha) and machinery energy (2074.89 MJ/ha). The total percentage of commercial energy sources were used in the cultivation of sugarcane crop like; diesel, electricity, chemical, fertilizer and machinery is varied as diesel (14.55%), electricity (71.94%), chemical (0.19%), fertilizer (11.32%) and machinery (1.98%).

That maximum energy use was found from commercial energy sources, the contribution of

electric energy 75191.31 MJ/ha and the percentage of electric energy contributing in the cultivation of sugarcane crop is about 71.94%. Followed by the diesel energy is involved in sugarcane cultivation 15211.46 MJ/ha and percentage of contribution is about 14.55%.

3.2 Non-Commercial Energy Sources (MJ/ha)

During the study of non-commercial energy sources from the selected area of Narsinghpur (M.P.). Shown in Fig. 2 we found that the farmers were used non-commercial energy sources like; human, animal and FYM energy sources. For human energy (5819.21 MJ/ha), animal energy (116.10 MJ/ha) and FYM energy (180 MJ/ha). The percentage of non-commercial energy sources like; human, animal and FYM is varied as human (95.15%), animal (1.89%) and FYM (2.94%) in the sugarcane crop.

That maximum energy use was found from non-commercial energy sources, the contribution of human energy 5819.21 MJ/ha and the percentage of human energy contributing in the cultivation of sugarcane crop is about 95.15%. Followed by the animal and farm yard manure (FYM) energy is involved in sugarcane cultivation 116.1 MJ/ha (animal) and 180 MJ/ha (FYM) and the percentage of contribution both non-commercial energy sources are about 1.89% and 2.94%.

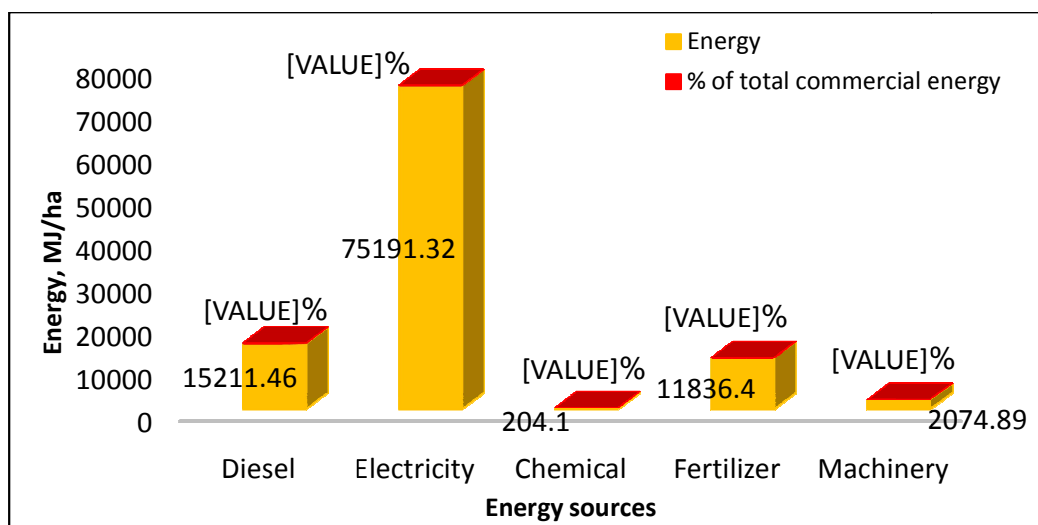


Fig. 1. Commercial energy sources (MJ/ha) in Narsinghpur (Madhya Pradesh).

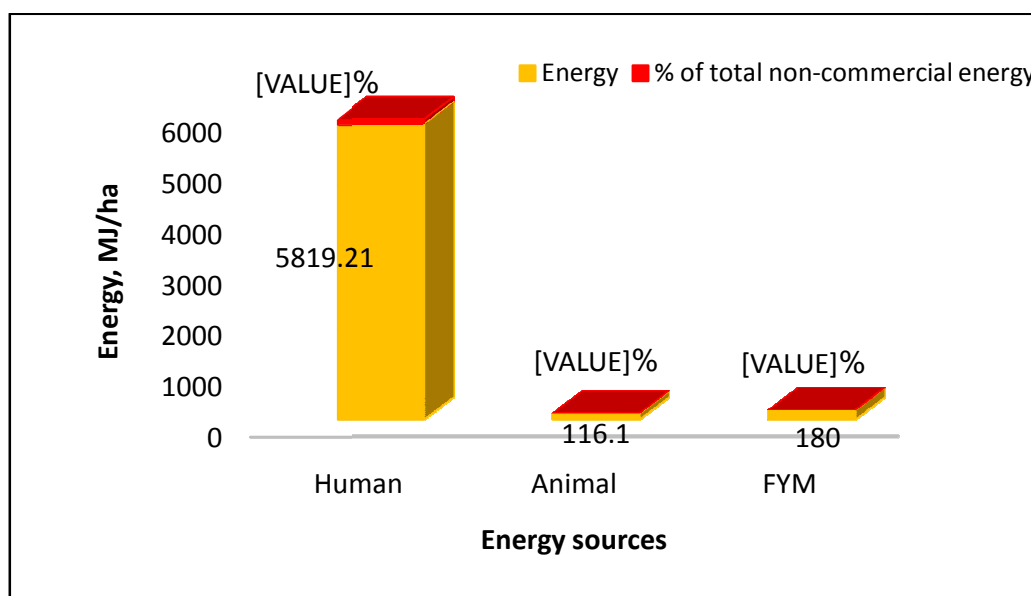


Fig. 2. Non-commercial energy sources (MJ/ha) in Narsinghpur (M.P.)

3.3 Commercial and Non-commercial Energy Ratio to Productivity

Over the years of study, table 2, shown there is an increased dependency on a commercial source of energy and reduction in the non-commercial source of energy resulting in increased productivity. This correlation is evidenced from the following table 2, for selected area of Narsinghpur the commercial and non-commercial energy ratio to the productivities are 0.91, 0.81, 0.68, 0.70, 0.87, 0.90, 0.77, 0.74, 0.71 and 0.93 kg/MJ.

3.4 Use of Electric Energy in Irrigation for Sugarcane

The crop sugarcane was grown by the farmers after paddy crop. It is also cultivated by the farmers had fellow land during kharif. In Narsinghpur "Havelli" system was used in which rainfall water is stored during rainy season. In this system land used to be sloppy at the centre like ponds so, water do not loss by runoff. In the Narsinghpur most of the farmers possessed tube well and the farmers, who did not have water source, hired the irrigation water from neighbouring farms.

The use of electric energy which are situated from commercial energy sources in the sugarcane is most important thing for better cropping yield of sugarcane. The process of

irrigation in sugarcane crop is done by using an electric motor for water lifting pump. The contribution of electric energy in sugarcane farming in the selected area of the study is varying between 100122.5MJ/kg (maximum) and 55623.6 MJ/kg (minimum) during the study period.

Higher irrigation energy means either higher number of irrigation or more hours of water supply in each irrigation. In these years the water reached to the plants by free flow. Most of the farms had slope for movement of the water. The variation in irrigation energy was too much and there were few farmers who did not apply any irrigation and totally dependent on winter or summer rains. The results revealed that un-irrigated fields average yield was only 625 q/ha which was less than half of the average yield in the selected area of Narsinghpur.

The choice of sugarcane crop by the farmers has been based on the availability of assured irrigation. The farmers without assured irrigation did not incline to select sugarcane crop rather they selected other crops like; wheat, urid, black gram, green gram etc.

It means in the selected area Narsinghpur, there was a significant enhancement in the yield of sugarcane with increased in water supply during the cropping period of sugarcane. Above fact can also be seen when this relationship is drawn for individual farmer.

Table-3. Commercial and non-commercial energy sources (MJ/ha) in Narsinghpur (Madhya Pradesh), India

Item	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10
Commercial energy sources (MJ/ha)										
Diesel	20395.48	17141.89	14540.36	10703.4	10443.25	13072.36	9960.11	29210.81	16538.24	10108.77
Electricity	100122.5	84430.8	77873	77873	72310	77873	66748.3	83435.4	55623.6	55623.6
Chemical	538	-	150	180	303	360	150	360	-	-
Fertilizer	20400	8415	10015	9818	10123	20400	11577	11959	7828.5	7828.5
Machinery	2491.45	2321.96	2032.95	1674.14	1605.49	1741.88	1819.91	3003.36	2615.79	1442.05
Total	143947.43	112309.64	104611.31	100248.54	94784.74	113447.24	90255.32	127968.46	82606.13	75002.92
Non-commercial energy sources (MJ/ha)										
Human	6096.4	4469.78	5147.83	5869.22	5584.53	9927.89	5752.6	5599.72	4936.26	4807.88
Animal	-	404	-	-	-	-	606	-	151	-
FYM	600	-	-	300	-	450	-	450	-	-
Total	6696.4	4873.78	5147.83	6169.22	5584.53	10377.89	6358.6	6049.72	5087.26	4807.88
Grand total	150643.83	117183.42	109759.14	106417.76	100369.27	123825.13	96613.92	134018.18	87693.39	79810.8
Yield q/ha	1375	950	750	750	875	1125	750	1000	625	750
Productivity kg/MJ	0.91	0.81	0.68	0.70	0.87	0.90	0.77	0.74	0.71	0.93

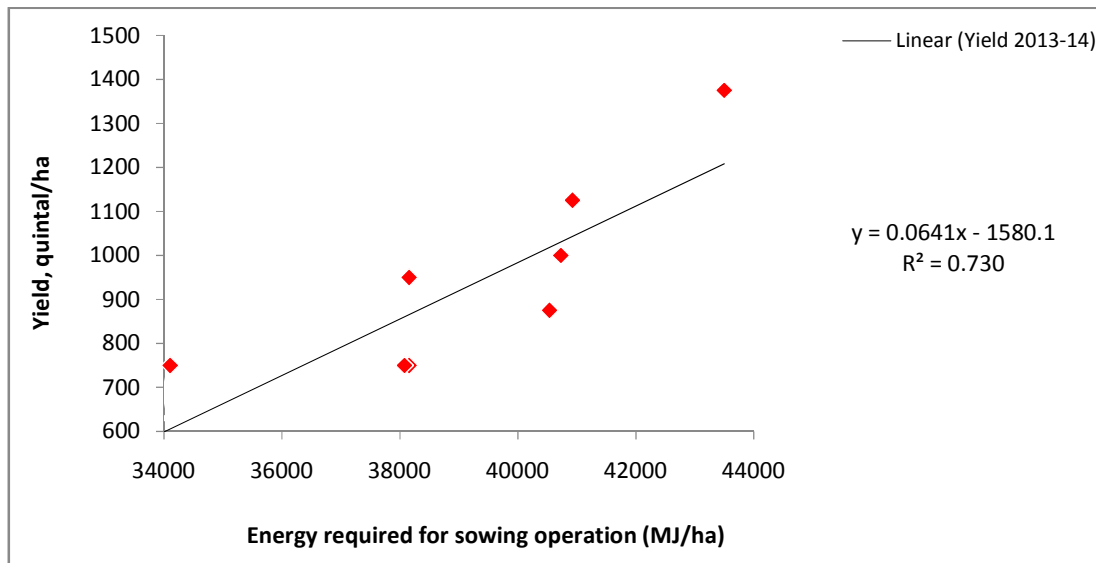


Fig. 3. Effect of sowing on yield of sugarcane in Narsinghpur, (M.P.), India

3.5 Effect of Sowing on Yield

Effect of sowing on yield can be evaluated separately for selected area in survey. The relationship between sowing and yield is shown in Fig. 3. The sowing energy consumption pattern under tractor farming system shows that on an average the sowing energy consumption was 38616.83 MJ/ha. The tractor farming was more useful for sugarcane cultivation. The value for yield showed a great production on an average value of 10 farmers from the selected area was 895 q/ha respectively. The higher productivity under tractor farming reveals that the farmers under this farming systems were from mainly medium farm categories. These are the farmers who are not lacking as far as the physical inputs like fertilizers and water as well they had close look to their farming operations this resulted in to higher output-input energy ratio. Their relationship can be seen in the equation given below:

$$y = 0.0641x - 1580.1 \quad (4.2)$$

$$(R^2 = 0.7301)$$

Considering sowing as predictor and yield of sugarcane as response for all equations derived by statistical analysis using software MS-Excel. Fig.3.

The relationship between yield and sowing energy is positive and direct. However statistically their relation is significant. Value of $R^2 = 0.730$.

4. CONCLUSION

Optimization of energy inputs (commercial and non-commercial energy inputs) are done on the basis that with the application of zero inputs in the field the production will be zero. To make the unique uniformity in independent variables (inputs) the quantity or level is converted into energy. The use of total energy was highest in tractor farms followed by the animal farms for sugarcane cultivation, tractor farms were followed by animal farms. The sowing energy consumption pattern under tractor farming system, the consumption of energy was found 38616.83 MJ/ha. The maximum use of diesel energy occurred in tractor farms which accounted for energy consumption 15211.46 MJ/ha it is an average value of diesel energy which are using by all farmers, which are randomly selected for the study of commercial and non-commercial energy sources in cultivation of sugarcane crop in the selected area of study Narsinghpur, (M.P.) India.

CONSENT

As per international standard or university standard written participants' consent has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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