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Research Paper

Evaluation of Energy Efficient Production System through Combined Effects of Tillage and Bioregulators on Chickpea (*Cicer arietinum* L.)

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ABSTRACT

To study the energy use in chickpeas, a field trial was conducted at Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh, India, during *rabi* season 2020-21. The experiment was laid out in split plot design with 3 main plot treatments *viz.* conventional tillage (CT), zero tillage (ZT), zero tillage with black gram crop residue @ 5t/ha (ZT+R), and five subplot treatments *viz.*, control or water spray, salicylic acid (50 ppm), Potassium nitrate (2%), Thiourea (1000 ppm), and Potassium + Multi-micronutrient complex (1%). Among different tillage treatments, ZT+R recorded the highest total energy output, net energy output, energy use efficiency, energy productivity, energy profitability, human energy profitability, energy output efficiency, and energy intensity in economic terms, followed by ZT and CT. Energy intensiveness and specific energy were reported highest under CT followed by ZT and ZT+R. Among bioregulators, foliar applications of KNO_3 (2%) at flower initiation and pod filling recorded maximum in net energy output returns, human energy profitability, energy output efficiency, and energy intensity in economic terms as compared to other treatments under ZT+R. While energy use efficiency, energy productivity, energy profitability, and energy intensiveness were reported same levels in KNO_3 (2%) and SA (50 ppm) under ZT+R although specific energy was comparatively higher under SA (50 ppm) application. Therefore, it was concluded that the adoption of foliar application of KNO_3 (2%) at flower initiation and pod filling stages under zero tillage with the addition of black gram residues @ 5t/ha in rainfed chickpeas could be an energy efficient which may help in realizing higher net returns in Bundelkhand regions of Jhansi.

HIGHLIGHTS

- Adoption of zero tillage with black gram crop residue @ 5t/ha (ZT+R) enhanced the chickpea's total energy output, energy use efficiency, energy productivity and profitability.
- Application of KNO_3 (2%) at flower initiation and pod filling recorded maximum in net energy output, energy output efficiency and human energy profitability.

Keywords: Chickpea, zero tillage, rainfed, bioregulators, energy productivity

Pulses are grain legumes that can be grown under the diverse agroclimatic condition with limited input supply (Sagar *et al.* 2022). Chickpea (*Cicer arietinum L.*) is an important pulse crop of India that occupies the highest share in area and production among the pulses (Choudhary *et al.* 2017). In general, chickpea is mainly grown in rainfed areas and marginal soils of India and are subjected to

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various biotic and abiotic challenges. Although Bundelkhand region is known as the mini pulse bowl of India, which comprises seven districts of Uttar Pradesh (Jhansi, Hamirpur, Mahoba, Banda, Lalitpur, Chitrakoot, and Jalaun) and seven districts of Madhya Pradesh (Tikamgarh, Chhatarpur, Panna, Sagar, Datia, Damoh, and Niwari), with 0.88 million hectares area, 1.180 million tonnes production and 1.36 t/ha productivity of chickpea (GoI, 2019). Bundelkhand region has favorable conditions for pulse production but still has low productivity as compared to China, mainly due to the occurrence of frequent droughts coupled with shallow soils and low water holding capacity. In this scenario, the availability of bio-regulators opened up a new window for enhancing crop yields under stress conditions. Bio-regulators have a pivotal role in crop growth, development, and source-to-sink relationships to enhance crop yield (Hossain *et al.* 2022). Moreover, the utilization of high energy input worsened this situation resulting in narrow net returns (Harika *et al.* 2020; Ghosh *et al*. 2021). Chickpea being a bold-seeded crop, does not require fine tilth and can be grown with limited ploughing after the harvest of the previous crop. This offers scope to adopt zero tillage and improve energy efficiency. Keeping all this in view, an initiative has been taken up to evaluate the energetics of rainfed chickpea through the combined effects of tillage and bioregulators in the Bundelkhand region.

MATERIALS AND METHODS

The present study was carried out at Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh, India, during *rabi* season 2020-21. The experimental site was located at 25°31′07.1″ N latitude and longitude of 78°33′47.4 E at 284 meters above mean sea level (MSL). The experiment was laid out in a split-plot design in which three levels of tillage, namely conventional tillage, zero tillage, and zero tillage with black gram crop residue (5t/ha) were allotted to the main plot and five different bioregulators namely control or water spray, salicylic acid (50 ppm), Potassium nitrate (2%), Thiourea (1000 ppm), and Potassium + Multi-micronutrient complex (1%) were allotted to subplots and applied as a foliar spray at flower initiation and pod filling stage. The experimental chickpea crop variety RVG-202 (Desi chickpea) was uniformly applied at 60kg/ha basis with 20 kg nitrogen, 50 kg phosphorus/ha, and 20 kg K_2O/ha applied as recommended dose of fertilizer. The crop received 2.0, 1.0, 3.8, 4.6, and 4.2 mm of precipitation on 47th, 6th, 7th, 11th and 12th meteorological weeks, respectively. However, 15.6 mm of total rainfall was received by chickpeas thought the growing season, although that rainfall was not enough for higher growth and yield.

Methods of energy budgeting: In the present investigation, all the input energy in the chickpea cultivation was used except built-in sources like as inherent soil fertility, solar radiation, and wind because it has no cost of opportunity (Chaudhary *et al.* 2017). Moreover, all the inputs were independent regarding respective management practices during the investigation. All the required inputs for chickpea production were collected, determined, and presented based on particular input energy equivalent as described by Singh and Mittal (1992). Common input requirements in different treatments of chickpea production were a seed, human labor, machinery, fertilizer, pre-sowing irrigation water, Diesel fuel, and pesticide. Grain and straw were the output products. The energy equivalent of different inputs and outputs were used to determine the energy values (Table 1). The energy used by particular input was calculated by multiplying with respective energy coefficients (Tuti *et al.* 2012) for converting the inputs in terms of energy (MJ/ha) from (Table 1). The flow chart of the methodology of calculation of various energy indices is presented below:

Energy input: All the input energy (MJ/ha) as calculated by multiplying the quantity of material used in the crop production process by the respective energy equivalents (Tuti *et al.* 2012).

Energy output: Energy outputs i.e., grains and straw, were computed by multiplying the quantity with its corresponding energy equivalents.

Based on energy input and output Mittal and Dhawan (1988) and Burnett (1982) suggested the following equations and formulas calculate; net energy returns, energy ratio, specific energy, energy intensiveness, energy profitability, and human energy profitability.

Net energy returns: Difference between energy output and the energy input.

Table 1: Energy equivalent for different input, output and machinery

Tillage	Quantity	Energy equivalent (MJ)	References
(A) Inputs			
1. Human labour			
(a) Adult man	MJ/h	1.96	Singh and Mittal (1992)
(b) Adult women	MJ/h	1.57	Singh and Mittal (1992)
2. Diesel	MJ/l	56.3	Singh and Mittal (1992)
3. Electricity (kwh)	kWh	11.93	Singh and Mittal (1992)
4. Chemicals and fertilizers			
(a) Nitrogen	MJ/kg	78.1	Kitani (1999)
(b) Phosphorus	MJ/kg	17.4	Kitani (1999)
(c) Potash	MJ/kg	13.7	Kitani (1999)
(d) Herbicides	MJ/kg or litre	288	West and Marland (2005)
(e) Fungicides	MJ/kg or litre	196	West and Marland (2005)
5. Machinery			
(a) Knapsack sprayer	MJ/h	0.26	Mandal *et al.* (2002)
(b) Tractor 45 hp	MJ/h	303.6	Dagistan *et al.* (2009)
(c) Machinery	MJ/kg	62.7	Sidhu *et al.* (2015)
6. Straw/Stover			
moongbean straw(Dry)	MJ/kg	12.5	Singh and Mittal (1992)
7. Cultivator	MJ/hr	22.8	Dagistan *et al.* (2009)
8. Harrow	MJ/hr	37.62	Dagistan *et al.* (2009)
9. Pre sowing irrigation	M^3	1.02	Singh *et al.* (2008)
(B) Output			
(a) chickpea (grain)	MJ/kg	14.7	Mandal *et al.* (2002)
(b) Chickpea stover(dry)	MJ/kg	12.5	Mandal *et al.* (2002)
(C) Machinery			
(a) Happy seeder	MJ/h	31.1	Sidhu *et al.* (2015)
(b) Seed drill	MJ/h	12.5	Dagistan *et al.* (2009)

1. $\text{Energy ratio} = \dfrac{\text{Gross energy output}}{\text{Energy input}}$

2. $\text{Specific energy (MJ/kg)} = \dfrac{\text{Input energy}}{\text{Grain yield}}$

3. $\text{Energy intensiveness} = \dfrac{\text{Energy input (MJ/ha)}}{\text{Cost of cultivation (Rs/ha)}}$

4. $\text{Energy profitability} = \dfrac{\text{Net energy returns (MJ/ha)}}{\text{Input energy (MJ/ha)}}$

5. $\text{Human energy profitability} = \dfrac{\text{Output energy (MJ/ha)}}{\text{Labor energy (MJ/ha)}}$

6. $\text{Energy productity (kg/MJ)} = \dfrac{\text{Yield output (Grain+Stover)}}{\text{Input energy}}$

7. $\text{Energy output efficiency (MJ/day)} = \dfrac{\text{Gross energy output}}{\text{Duration of the croppimg period}}$

8. $\text{Energy intensity in economic term(MJ/₹)} = \dfrac{\text{Gross energy output}}{\text{Cost of cultivation}}$

RESULTS AND DISCUSSION

Energy input requirement of crops: Perusal of the data presented in Table 2 represents that the common input energy required for chickpea production was 6331.46 MJ/ha (100%). We know that pre-sowing irrigation is an important input for the successful cultivation of *rabi* season crops under the rainfed situation. Pre-sowing irrigation energy share 28.34% of total common energy inputs. Only seed contributes 13.93% of total common energy input for crop production while sowing of seeds and intercultural operations, viz, gap filling, accounted for 7.11% and 0.50% of total common energy input, respectively. Fertilizers application contributes a maximum share (42.73%) of total standard energy input. However, it was applied at the rate of 20 kg N/ha 50 kg P_2O_5/ha, and 20 kg K_2O/ha as per recommendation for standard package and practices for chickpea production. Energy required for spraying plant protection chemicals shared 4.91% of total standard energy inputs. Energy requirement for the harvesting and Threshing process accounted for 2.46% of the total standard energy input for production.

Table 2: Common input energy of chickpea under different tillage and bioregulators practices

Operation	Used quantity per ha	Energy equivalent (MJ)	Total energy (MJ/ha)
Fertilizers			
Nitrogen	20 kg	78.1	1562
Phosphorus	50 kg	17.4	870
Potash	20 kg	13.7	274
Seed			
Chickpea	60 kg	14.7	882
Intercultural operations			
Gap filling	2 man days	1.96	31.4
Pre-sowing irrigation			
Water	600m^2	1.02	612
Irrigation	96.5 kwh	11.93	1151.2
Application cost	2 man days	1.96	31.4
Plant protection			
Dithane M-45 75%WP	1.5 kg *a.i.*	196	294
Knapsack sparer	8 hrs	0.17	1.36
Application cost	1 man days	1.96	15.6
Harvest			
Harvesting and Threshing manual	9 man days	1.96	140.4
Diesel	8 L	56.3	450.5
Human labour	1 man days	1.96	15.6
			6331.46

Energy used in different tillage treatments of crop cultivation is represented in Table 3. Energy required for Conventional tillage was highest among all tillage treatments (5344 MJ/ha) in which additional cultivator, harrow, and planked is needed for proper seedbed preparation, while in zero tillage and zero tillage with residue (residue not included) treatment required the same amount of input energy (1434.10 MJ/ha) because additional inputs were not needed in the treatments only direct sowing was done by happy seed drill machine like conventional tillage.

Table 3: Energy input requirement for different tillage treatments

Tillage	Quantity	Energy equivalent (MJ)	Total energy (MJ/ha)
Conventional tillage			
Pendamithalin	1 kg	288	288
Tractor + Cultivator	3 hrs	341..2	1023.6
Tractor + Harrow	1.5 hrs	326.4	489.6
Tractor + Planker	1.5 hrs	326.4	489.6
Tractor + Happy Seed drill	2.5 hrs	316.14	790.4
Diesel	39.8 l	56.31	2241.1
Driver + Labour	11 man hours	1.96	21.6
			5344
Zero tillage			
Glyphosate	1.23 kg	288	354.2
Knapsack sprayer	4 hrs	0.26	1.04
Application	4 man hours	1.96	7.84
Happy Seed Drill + Tractor	1.5 hrs	334.69	502.0
Diesel	10 l	56.31	563.1
Driver + Human labour	3 man hrs	1.96	5.9
			1434.1
Zero tillage + Residue			
Glyphosate	1.23 kg	288	354.2
Knapsack sprayer	4 hrs	0.26	1.04
Application	0.5 man days	1.96	7.84
Happy Seed Drill + Tractor	1.5 hrs	334.69	502.0
Diesel	10 l	56.31	563.1
Driver + Human labour	3 man hrs	1.96	5.9
			1434.1

Energy used between bioregulators treatments of crop cultivation is represented in Table 4. Among bioregulators energy consumed by 1% potassium + Multimicronutrient complex (255.7MJ/ha) followed by potassium nitrate (218.7MJ/ha), thiourea (138.7MJ/ha), salicylic acid (24.7MJ/ha) and minimum total energy input was consumed by water spray or control (18.7 MJ/ka).

Table 4: Energy input requirement for different Bioregulators treatments

Bioregulators	Quantity per ha	Energy equivalent (MJ)	Total energy (MJ/ha)
Water			
Water	1m^3	1.02	1.02
Knapsack sprayer	8 hrs	0.26	2.08
Application	1 man days	1.96	15.6
			18.7
Salicylic acid	0.05kg	120	6
Water	1m^3	1.02	1.02
Knapsack sprayer	8 hrs	0.26	2.08
Application	1 man days	1.96	15.6
			24.7
KNO_3	20 Kg	10	200
Water	1m^3	1.02	1.02
Knapsack sprayer	8 hrs	0.26	2.08
Application	1 man days	1.96	15.6
			218.7
Thiourea	1Kg	120	120
Water	1m^3	1.02	1.02
Knapsack sprayer	8 hrs	0.26	2.08
Application	1 man days	1.96	15.6
			138.7
K + multimicronutrient	10+10 kg	13.7+10	237
Water	1m^3	1.02	1.02
Knapsack sprayer	8 hrs	0.26	2.08
Application	1 man days	1.96	15.6
			255.7

Energy input-output relationship: The total energy input (MJ/ha) utilized and total output energy produced (MJ/ha) in each treatment during crop production has been presented in Table 5. Based on the quantity of material used in crop production by the respective energy equivalents used as input energy and treatment-wise energy production of output was calculated based on seed and haulm yield of respective treatments. Minimum total output energy is produced by foliar application of water (control) under conventional tillage (43.26×10^3 MJ/ha); however, it was because of its poor yield output as compared to foliar application of under zero tillage with residue retention (53.62×10^3 MJ/ha) was recorded highest total energy output among all treatments due to more moisture conservation leads to more yield and subsequently total energy output. However, among conventional and zero tillage treatments were reported highest energy output (46.71×10^3 MJ/ha and 50.91×10^3 MJ/ha, respectively) by foliar application of salicylic acid (50ppm). It may be because salicylic acid improved grain yield and straw yield more than other treatments within the zero tillage and conventional tillage treatments under different levels of bioregulators.

Net energy returns: The net energy returns were higher under ZT+R treatment than ZT and CT (Table 5). ZT+R reported higher yield output than ZT and CT, which resulted in more net energy returns. Higher energy incurred on CT tillage and comparatively lower biological yield leads to the lowest net energy returns. Among bioregulator application practices, foliar application of KNO_3 (2%) was reported to have the highest net energy return (45.64×10^3 MJ/ha)**.** It might be due to higher straw yield, while foliar application of SA (50ppm) was reported (44.50×10^3 MJ/ha) of net energy output because of higher grain yield as compared to Thiourea (42.68×10^3 MJ/ha) and water spray (40.34×10^3 MJ/ha). The net energy returns under ZT+R were 13, 10, 9 and 6% more with KNO_3, SA, K + multi-micronutrient, and thiourea alone, respectively, as compared to control. A similar trend was observed with the bioregulator application practices of ZT and CT. The ZT+R reported 3 and 27% more net energy returns than ZT and CT, respectively, with foliar application of SA (50ppm). Adoption of ZT+R performed better with fewer inputs and resulted in higher net energy returns.

Energy use efficiency: Energy ratio or energy use efficiency of treatments is represented in Table 5. The energy ratio was more under ZT+R comparatively compared to ZT and CT. Foliar application of SA(50ppm) and KNO_3(2%) showed more output per unit of input, as compared to other treatments. It is due to the highest grain and stover yields over other treatments. The ZT+R reported the highest same energy ratio (6.72) with both treatments viz, SA (50ppm) and KNO_3 (2%) than ZT (6.54 and 6.03 respectively) and CT (3.99 and 3.82 respectively).

Table 5: Energy use (x10[3] MJ/ha) in chickpea as influenced by tillage and bioregulators applications

Treatments	Common energy input	Tillage	Bioregulators	Total input energy	Total energy output
CT-Conventional tillage					
B_0 - Control (water spray)	6.33	5.34	0.009	11.69	43.26
B_1- Salicylic acid (50 ppm)	6.33	5.34	0.015	11.69	46.71
B_2- KNO_3 (2%)	6.33	5.34	0.209	11.89	45.45
B_3- Thiourea (1000 ppm)	6.33	5.34	0.129	11.81	45.32
B_4 - K + multi-micronutrient (1%)	6.33	5.34	0.246	11.93	42.88
ZT-Zero tillage					
B_0 - Control (water spray)	6.33	1.43	0.009	7.78	44.79
B_1- Salicylic acid (50 ppm)	6.33	1.43	0.015	7.78	50.91
B_2- KNO_3 (2%)	6.33	1.43	0.209	7.98	47.92
B_3- Thiourea (1000 ppm)	6.33	1.43	0.129	7.90	47.53
B_4 - K + multi-micronutrient (1%)	6.33	1.43	0.246	8.02	46.58
ZT+R Zero tillage + Residue					
B_0 - Control (water spray)	6.33	1.43	0.009	7.78	48.12
B_1- Salicylic acid (50 ppm)	6.33	1.43	0.015	7.78	52.29
B_2- KNO_3 (2%)	6.33	1.43	0.209	7.98	53.62
B_3- Thiourea (1000 ppm)	6.33	1.43	0.129	7.90	50.58
B_4 - K + multi-micronutrient (1%)	6.33	1.43	0.246	8.02	51.95

The lowest energy use efficiency was recorded with control of CT (3.70) over ZT (5.76) and ZT+R (7.70).

Specific energy: The ratio of energy input to economic yield is represented in Table 5. Specific energy under conventional tillage treatment was more when compared with ZT and ZT+R. it is due to the higher input energy with lower economic yield as compared to ZT and ZT+R tillage practices which resulted in higher specific energy under CT. Lower specific energy under ZT and ZT+R due to higher economic yield and lower energy input over CT. The specific energy with KNO_3 (2%) was less (6.38 MJ/ha) as compared to other bioregulator applications under ZT+R. However, lower input energy, as well as more economic yield with KNO3 (2%), resulted in lower specific energy (6.38 MJ/ha) under ZT+R as compared to ZT (8.14MJ/ha) and CT (13.36MJ/ha), respectively.

Energy productivity: The ratio of yield output (grain + straw) to energy input is represented in Table 5. Higher grain yield was recorded with foliar application of SA and KNO_3 followed by thiourea, K + multi-micronutrient, and control under ZT+R in terms of megajoule (MJ) of energy. Similarly, ZT and CT reported the energy produced on the same pattern of ZT+R. Amongst bioregulator applications, the highest productivity was reported under SA application, which was 0.51, 0.50, 0.31 MJ/kg under ZT+R, ZT, and CT, respectively.

Energy intensiveness: Perusal of the data presented in Table 6 showed the improvement in management practices or ratio of energy input to the cost of cultivation. Energy intensity or intensiveness is significantly affected by the biological yield of the crop. CT recorded the highest energy intensiveness as compared to ZT and ZT+R. It represented lower efficiency in the management of total input energy under conventional tillage as compared to ZT and ZT+R. Foliar application of thiourea (1000ppm) recorded minimum energy intensity under ZT+R treatment (0.27), and the same pattern was followed in CT (0.34) and ZT (0.27). Energy intensity wanted to produce 1 kg chickpea was highest (0.59) with control or water spray under CT treatment.

Energy profitability: The ratio of net energy returned to input energy is presented in table 6. Energy profitability represents the efficiency of management practices it increases when there is a decrease in management intensity. However it was strongly correlated with the sum of grain and straw production in a particular treatment. Tillage treatments influenced energy profitability,

Table 6: Energy analysis of chickpea as influenced by tillage and bioregulators applications

Treatment	Net energy returns ($x10^3$ MJ/ha)	Energy use efficiency	Specific energy (MJ/kg)	Energy productivity (kg/MJ)
CT-Conventional tillage				
B_0 - Control (water spray)	31.57	3.70	14.43	0.28
B_1- Salicylic acid (50 ppm)	35.01	3.99	12.71	0.31
B_2- KNO_3 (2%)	33.56	3.82	13.36	0.29
B_3- Thiourea (1000 ppm)	33.51	3.84	12.98	0.29
B_4 - K + multi-micronutrient (1%)	30.96	3.60	13.87	0.27
ZT-Zero tillage				
B_0 - Control (water spray)	37.01	5.76	8.74	0.44
B_1- Salicylic acid (50 ppm)	43.13	6.54	7.14	0.50
B_2- KNO_3 (2%)	39.94	6.01	8.14	0.46
B_3- Thiourea (1000 ppm)	39.63	6.02	8.31	0.46
B_4 - K + multi-micronutrient (1%)	38.56	5.81	8.91	0.45
ZT+R Zero tillage + Residue				
B_0 - Control (water spray)	40.34	6.19	7.70	0.47
B_1- Salicylic acid (50 ppm)	44.50	6.72	6.54	0.51
B_2- KNO_3 (2%)	45.64	6.72	6.38	0.51
B_3- Thiourea (1000 ppm)	42.68	6.40	7.38	0.49
B_4 - K + multi-micronutrient (1%)	43.94	6.48	6.91	0.49

and somehow, bioregulators' application also contributed to an increase in net return and, subsequent improvement in energy profitability. ZT+R recorded the highest energy profitability as compared to ZT and CT. Foliar application of SA (50ppm) recorded maximum energy profitability under ZT+R treatment (5.72), and the same pattern was followed in CT (2.99) and ZT (5.54). Energy profitability was lowest with control or water spray under CT (2.70), ZT (4.76), and ZT+R (5.19).

Human energy profitability: The ratio of total output energy to labor energy is presented in table 6. It was based on the outcome of the energy per unit use of human energy; however, it was highest under ZT+R as compared with CT and ZT treatment. It represented that ZT+R produced more output energy per unit of human energy used as compared to other tillage treatments. Among bioregulators application KNO_3 (203.30) recorded the highest human energy profitability, followed by Salicylic acid (198.26), K + multi-micronutrient (196.98), Thiourea (191.36) and control (182.44) under ZT+R. Concerning CT and ZT treatments, the highest human energy profitability was reported with foliar application of salicylic acid, KNO_3, Thiourea (1000 ppm), K + multi-micronutrient (1%), and control. It was due to bioregulators ing total output energy by improving total biomass yield and, finally, human energy profitability.

Energy output efficiency: The ratio of total output energy to total days to production is presented in table 6. It represented the intensity or speed of outcome of output energy concerning days. ZT+R recorded higher energy output efficiency as compared to CT and ZT. It is due to higher biomass energy production as compared to ZT and CT, however, there was ZT+R takes more days as compared to CT and ZT, but it was aggressively suppressed by more biomass production in ZT+R. Moreover, foliar application of KNO_3 (354.27) recorded the highest energy output efficiency followed by Salicylic acid (342.34), K + multi-micronutrient (339.60), Thiourea (336.51) and control (319.97) under ZT+R. Concerning CT and ZT treatments, the highest human energy profitability was reported with foliar application of salicylic acid, KNO_3, Thiourea (1000 ppm), K + multi-micronutrient (1%) and minimum in control. It may be due to application of bioregulators enhanced as well as boots some beneficiary physiological activities in plants which helped to increased total biomass production and subsequently energy output efficiency of the treatments.

Table 7: Energy analysis of chickpea as influenced by tillage and bioregulators applications

Treatment	Energy intensiveness (MJ/Rs)	Energy profitability	Human Energy profitability	Energy output efficiency (MJ/day)	Energy intensity in economic term (MJ/Rs)
CT-Conventional tillage					
B_0 - Control (water spray)	0.38	2.70	159.28	301.23	1.39
B_1- Salicylic acid (50 ppm)	0.38	2.99	171.97	320.00	1.50
B_2- KNO_3 (2%)	0.37	2.82	167.34	313.60	1.42
B_3- Thiourea (1000 ppm)	0.34	2.84	166.86	316.23	1.32
B_4 - K + multi-micronutrient (1%)	0.37	2.60	157.89	299.23	1.33
ZT-Zero tillage					
B_0 - Control (water spray)	0.30	4.76	169.83	296.61	1.73
B_1- Salicylic acid (50 ppm)	0.30	5.54	193.04	339.58	1.97
B_2- KNO_3 (2%)	0.30	5.01	181.68	317.45	1.79
B_3- Thiourea (1000 ppm)	0.27	5.02	180.21	319.07	1.64
B_4 - K + multi-micronutrient (1%)	0.30	4.81	176.60	312.53	1.73
ZT+R Zero tillage+Residue					
B_0 - Control (water spray)	0.29	5.19	182.44	319.97	1.82
B_1- Salicylic acid (50 ppm)	0.29	5.72	198.26	342.34	1.97
B_2- KNO_3 (2%)	0.29	5.72	203.30	354.27	1.95
B_3- Thiourea (1000 ppm)	0.27	5.40	191.76	336.51	1.70
B_4 - K + multi-micronutrient (1%)	0.29	5.48	196.98	339.60	1.88

Energy intensity in economic term: The ratio of gross energy output to the cost of cultivation is presented in table 6. ZT+R recorded higher energy intensity in an economic term than CT and ZT. It is due to higher biomass energy production as well as lower cost of cultivation as compared to ZT and CT; among bioregulators, foliar application of SA(1.97) recorded the highest energy intensity in economic terms followed by KNO_3 (1.95), K + multi-micronutrient (1.88), control (1.82) and Thiourea (1.70) under ZT+R. Moreover, concerning ZT treatment, the highest energy intensity in economic terms was reported with foliar application of salicylic acid (1.97), KNO_3 (1.79), control (1.73), K + multi-micronutrient (1.73) and minimum in Thiourea (1.64). It may be due to the application of some bioregulators being costly, resulting in somehow increase in the cost of cultivation as compared to water spray or control. Likewise, concerning CT treatment, the highest energy intensity in economic terms was reported with foliar application of salicylic acid (1.50), KNO_3 (1.42), control (1.39), K + multi-micronutrient (1.33), and minimum in Thiourea (1.32).

CONCLUSION

Based on this investigation as ZT+R recorded the highest total energy output, net energy output, energy use efficiency, energy productivity, energy profitability, human energy profitability, energy output efficiency, and energy intensity in economic terms, followed by ZT and CT. Among bioregulators, foliar applications of KNO_3 (2%) at flower initiation and pod filling recorded maximum in net energy output returns, human energy profitability, energy output efficiency, and energy intensity in economic terms compared to other treatments under ZT+R. Therefore, it can be concluded that the adoption of foliar application of KNO_3 (2%) at flower initiation and pod filling stages under zero tillage with the addition of black gram residues @ 5t/ha in rainfed chickpea could be an energy efficient which may help in realizing higher net returns in Bundelkhand regions of Jhansi.

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