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# ENERGY BUDGETING OF WHEAT USING DIFFERENT TILLAGE AND NUTRIENT MANAGEMENT PRACTICES IN BUNDELKHAND REGION OF INDIA

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**ABSTRACT**

A field experiment was carried out at agriculture research farm of Banda University of Agriculture & Technology, Banda (U.P.) during *rabi* season of two consecutive years 2023-24 and 2024-25. The experiment was laid out in split- split plot design comprised two main plots i.e. Conventional tillage and Zero Tillage, with three sub plots of wheat cultivars viz; HD 3226, HD 3249 and DBW 187 and three sub-sub plots of Recommended Dose of Fertilizers e.g. NPK100%, NPK125% and NPK150%. The experiment was replicated thrice. Adoption of zero tillage was found to be most energy efficient to wheat cultivation and had the lowest requirement for input energy (10.68%) as compared to conventional tillage. The mean values of output energy (147411.85 MJ/ha), net energy (127887.285 MJ/ha), energy ratio (7.57) and, energy productivity (0.26 kg/MJ) were higher in zero tillage. Among cultivars the maximum mean values for output energy (149213.25MJ/ha), net energy (128520.43 MJ/ha), energy ratio (7.25) and, energy productivity (0.25 kg/MJ) was recorded with DBW 187. In nutrient management practices output energy (151764.30 MJ/ha) and net energy gain (129019.98 MJ/ha) were higher in NPK 150%, however, the energy ratio (7.07) and energy productivity (0.24 kg/MJ) values were higher under NPK 100% treatment.

***Keywords*:** Zero Tillage, Conventional Tillage, input energy, output energy, net energy gain, and energy ratio and energy productivity.

## Introduction

Bundelkhand have always been a challenging place for survival of human, animals and plants. The majority of population is either dependent on the resource less low agriculture production or migrated seasonally to the industrial cities for employment. Interventions of innovative technologies i.e. zero tillage and nutritional fortification can be recourse the perception of Bundelkhand agriculture from subsistence to sustainable. With the increasing availability of water, cereal crops e.g. rice and wheat are rapidly replacing the pulses and oilseeds in the Bundelkhand region of Uttar Pradesh that built the confidence of farmers on agriculture in the region.

Wheat is one of the most important cereal crop cultivated worldwide for meet out the demand of burgeoning population every day. The wheat is known as the “king of cereals” due to the widespread cultivation, adaptability to diverse climates and soils, and its vital role as a staple food for the millions of peoples. Wheat is cultivating globally on 215.91 million hectares with 791.02 million metric tons annual production. India ranks second worldwide in terms of production (14%) followed by China (17%). Wheat is one of the most cereals in India also occupied 31.83 million hectares area and produces 113.29 million tonnes with a national average yield of 3559 kg/ha ((Agricultural Statistics at a Glance, 2023).

At present, agriculture production system relies on intensive use of non-renewable or fossil energy. These energy inputs are in direct forms such as diesel and electricity used for on-farm production activities such as land preparation, irrigation, intercultural operations, harvesting, threshing and, transportation of agricultural inputs and farm produce, and in indirect forms such as the energy used in the manufacturing and transport of seed, fertilizers, water, pesticides and farm machinery (Tiwari *et al*., 1988). All intensive energy inputs exert direct effect on the depletion of energy sources. Since wheat is cultivating widely, thus it is necessary to investigate it in depth in order to save energy for sustainable production (Ali *et al.,* 2013). The energy use for tillage in wheat production is a major direct expense in terms of fuel costs for farmers. High energy use for tillage is usually associated with high machinery costs and labor inputs, which varies considerably according to the tillage systems used (Kosutic *et al.,* 2005). An experiment performed by (Kumar *et al*., 2013) reported the conventional tillage is one of the most expensive and organizationally slow systems that use significantly greater energy and labor. Reduced and/ or zero tillage is increasingly attractive to farmers because it evidently reduces input costs such as fuel, labor, maintenance of machinery and depreciation costs as compared with a conventional tillage system (Smart and Bradford 1998).

There is a close relationship between agriculture and energy. The energy in agriculture is important for crop production and processing of agro food for value addition. A lot of human, animal and mechanical energy is used in agriculture crop production. Agriculture uses energy and the same is reciprocated in the form of bio-energy. At present time, the productivity and profitability of agriculture depend upon the ratio of energy consumption and output.

## Materials and Methods

### Site of the Experiment

A two-year field study was conducted in the rabi season of 2023-24 and 2024-25 at agriculture research farm of Banda University of Agriculture & Technology, Banda, Uttar Pradesh, India that lies between 25.53° N, 80.33° E, and at an altitude of 228.61 m above mean sea level. This region is characterized as hot and semi-arid climate. Annual rainfall of this region is ranging from 750 mm to 950 mm. The soil of experimental site was sandy clay loam in texture (68.592% sand, 11.216% silt and 20.192% clay) and pH was 7.71.

### Detail of treatments and experimental design

The experiment was plan in spilt-split plot design with three factors e.i. main factor (conventional tillage and zero tillage), sub factor (wheat cultivars HD 3226, HD 3249 and DBW 187) and in sub- sub factor (3 NPK levels-100% NPK, 125% NPK and 150% NPK). All 18 combinations of treatments (Table 1) were replicated 3 times. The recommended dose of fertilizers was 120 kg N, 60 kg $P_2O_5$ and 40 kg $K_2O$.

**Table 1:** Details of treatments.

| **A. Main Plots** (Tillage) | **Treatments combinations** | |
|---|---|---|
| | $T_1$ | Conventional Tillage + HD- 3226+ 100 % NPK |
| Conventional tillage<br>Zero tillage | $T_2$ | Conventional Tillage + HD- 3226+ 125 % NPK |
| | $T_3$ | Conventional Tillage+ HD- 3226+ 150 % NPK |
| | $T_4$ | Conventional Tillage + HD- 3249+ 100% NPK |
| **B. Sub Plots** (Wheat cultivars) | $T_5$ | Conventional Tillage+ HD- 3249+ 125% NPK |
| HD3226<br>HD3249<br>DBW187 | $T_6$ | Conventional Tillage+ HD- 3249+ 150% NPK |
| | $T_7$ | Conventional Tillage + DBW-187+ 100% NPK |
| | $T_8$ | Conventional Tillage + DBW-187+125% NPK |
| | $T_9$ | Conventional Tillage + DBW-187+150% NPK |
| **C. Sub-sub plots (NPK levels)** | $T_{10}$ | Zero Tillage + HD- 3226+ 100% NPK |
| 100% NPK<br>125% NPK<br>150% NPK | $T_{11}$ | Zero Tillage + HD- 3226+125% NPK |
| | $T_{12}$ | Zero Tillage + HD- 3226+150% NPK |
| | $T_{13}$ | Zero Tillage + HD- 3249+100% NPK |
| | $T_{14}$ | Zero Tillage + HD- 3249+125% NPK |
| | $T_{15}$ | Zero Tillage + HD- 3249+150% NPK |
| | $T_{16}$ | Zero Tillage + DBW-187+100% NPK |
| | $T_{17}$ | Zero Tillage + DBW-187+125% NPK |
| | $T_{18}$ | Zero Tillage + DBW-187+150% NPK |

*Note:* 100% NPK:(120,60,40 NPK kg/ha), 125% NPK:(150,75,50 NPK kg/ha) and 150% NPK:(180,90,60 NPK kg/ha)

## Crop management

In conventional tillage, wheat was sown after harvesting of previous kharif season paddy crop. Field was prepared with the help of two cross harrowing and one rotavator for the sowing of wheat crop. In zero tillage, wheat was sown in the unprepared stubble field of the previous rice crop. Before sowing seed was treated with the fungicide bavistine at the rate of 2g/kg and sowing was done by seed drill in conventional tillage and by zero till seed drill in zero tillage. The dose of fertilizers were applied according to the treatment, however, half dose of N and full dose of $P_2O_5$ and $K_2O$ were applied as basal and remaining dose of N was applied in two equal splits first after 21 DAS and second 50 DAS in all the plots. Four irrigations were applied to each treatment at the moisture critical stages. After sowing pre-emergence herbicide pendimethalin (30 EC) 0.75 ltr/ha was applied with knapsack sprayer followed by one manual weeding in both conventional and zero tillage.

**Table 2 :** Energy equivalent (EE) for various input and output sources

| Sr. No. | Particulars | Units | Equivalent energy (MJ) | References |
|---|---|---|---|---|
| A | **Inputs** | | | |
| 1 | **Direct Energy** | | | |
| i | **Human power** | | | |
| | Adult man | Man-hour | 1.96 | Nandan *et al*. (2021), Shyam Lal *et al.* (2016), Ali *et al*. (2013), Kumar *et al*. (2013), Devasenapathy *et al.,* (2009) |
| | Woman | Man-hour | 1.57 | Nandan *et al*. (2021), Shyam Lal *et al.* (2016), Devasenapathy *et al.*(2009) |
| ii | **Diesel fuel** | Liter | 56.31 | Nandan *et al*. (2021), Shyam Lal *et al.* (2016), Ali *et al*. (2013), Kumar *et al*. (2013), Devasenapathy *et al.*(2009) |
| 2 | **Indirect energy** | | | |
| i | **Machinery** | | | |
| a | **Farm machinery** | | | |
| | Disk harrow, cultivator, seed drills, rotavator, sprayers | kg | 62.7 | Devasenapathy *et al.* (2009), Ali *et al.* (2013), Nandan *et al.* (2021) |
| b | **Prime movers** | | | |
| | Tractor, 5 hp motor | kg | 64.8 | Devasenapathy *et al.* (2009), Nandan *et al*. (2021) |
| ii | Water | $m^3$ | 1.02 | Shyam Lal *et al.* (2016), Singh *et al.*(2008), Nandan *et al.* (2021), Azarpour (2012) |
| iii | Seed (Wheat) | kg | 14.7 | Devasenapathy *et al.* (2009), Kumar *et al.* (2013), Ali *et al.* (2013) |
| iv | **Fertilizers** | | | |
| | Nitrogen (N) | kg | 60.6 | Devasenapathy *et al.* (2009), Shyam Lal *et al.* (2016), Nandan *et al.* (2021), Tuti *et al.*(2012) |
| | Phosphorus ($P_2O_5$) | kg | 11.1 | |
| | Potash ($K_2O$) | kg | 6.7 | |
| v | Chemicals (Herbicide) | kg | 120 | Ali *et al.* (2013), Kumar *et al*. (2013), Devasenapathy *et al.* (2009) |
| **Output** | | | | |
| 1 | Main product (Wheat grain) | kg | 14.7 | Devasenapathy *et al*. (2009), Kumar *et al*. (2013) |
| 2 | By product (Wheat straw) | kg | 12.5 | Devasenapathy *et al*. (2009), Nandan *et al*. (2021), Shyam Lal *et al*. (2016), Kitani (1999) |

## Energy budgeting

Energy budgeting in agriculture entails the examination of energy inputs and outputs within production systems to enhance efficiency and sustainability. It is a method to comprehend energy utilization in agricultural production, from planting to harvesting and beyond, and to pinpoint areas for optimization of energy consumption. There were various inputs and energy is required for the cultivation of wheat crop. Such inputs and energy include farm machineries, fuel, men & women labour, seed, irrigation water, chemical fertilizers, herbicides, fungicides and pesticides. The output of wheat crop was amount of grain and stover production. The energy input and output were calculated and energy inflow and outflow budgeting was computed. Calculation of energy sources computed according to the energy requirement and their corresponding energy equivalents given in Table 2.

**Energy indices**

Based on the energy input and output; the following parameters such as input energy, output energy, net energy gain, energy ratio (energy efficiency) and, energy productivity was computed by using the formula given by Tabatabaeefar *et al.* (2009), Burnett (1982), Devasenapathy *et al.* (2009), Mittal and Dhawan (1988), Tuti *et al.* (2012), Chaudhry *et al.* (2017) and Kumar *et al.* (2019).

**Input energy (Ei)**

$$E_i = \mathrm{BE} + \mathrm{ChE} + \mathrm{FOE}$$

Where, **BE:** Biological Energy, **ChE:** Chemical Energy, **FOE:** Field Operation Energy.

**Biological energy (BE)**

$$\mathrm{BE} = \text{labour} \times \text{working hours ha}^{-1} \times \mathrm{EE}\ (\text{energy equivalent})$$

**Chemical Energy (ChE)**

$$\mathrm{ChE} = \mathrm{FE} + \mathrm{TE}$$

Where,

**FE:** Fertilizer energy (MJ), **TE:** Toxin energy (MJ).

$$\mathrm{FE} = \mathrm{WF}(N)\times[\mathrm{EM}(N)\times \mathrm{E}(N)] + \mathrm{WF}\,(P)\times[\mathrm{EM}(P)\times \mathrm{E}(P)$$

$$\mathrm{TE} = \sum(\mathrm{Wt}\times \mathrm{et}\times \mathrm{Em} + \mathrm{Wt}\times \mathrm{nt}\times \mathrm{Nm})$$

Where, **WF (N):** the recommended dose of fertilizer (kg ha$^{-1}$), **EM (N):** the pure fertilizer percent; and **E (N):** the energy required to product pure fertilizer. Notations of WF (P), EM (P) and E (P) correspond to above notations; P in the parentheses is phosphor. **Wt:** weight of toxin (kg), **et:** pure toxin percent, **Em:** energy required for pure production (MJ kg$^{-1}$), **nt:** gross toxin percent, and **Nm:** energy required for gross production (MJ kg$^{-1}$).

**Field operation energy (FOE)**

Energy for FOE was considered to be fuel energy plus energy of machinery operations.

$$EF = Q_i \times EE$$

Where, **FE:** fuel energy (MJ L$^{-1}$), **Qi:** fuel consumption (Lh$^{-1}$), **EE:** equivalent energy.

Energy related to tractor or machine operations was determined by the following equation.

$$\mathrm{MaE}: (m \times ee) \times Fe/u$$

Where, **MaE:** Energy for tractor or machine (MJ ha-1), **m:** mass (kg), **ee:** yearly energy for equipment, **u:** the working hours per years and, **Fe:** operational work capacity (h ha$^{-1}$).

**Output energy ($E_o$)**

$$E_o = (E_{mp} \times EE) + (E_{bp} \times EE)$$

Where, **$E_{mp}$:** Main product energy (wheat grain yield kg/ha), **$E_{bp}$:** By product energy (straw yield kg/ha), **EE:** equivalent energy.

**Net Energy Gain (NEG)**

$$\mathrm{NEG} = \text{Output energy } E_o(\mathrm{MJ/ha}) - \text{Input energy } E_i(\mathrm{MJ/ha})$$

**Energy ratio (ER)**

$$ER = \frac{Output\ energy\ E_o\ (MJ/ha)}{Input\ energy\ E_i(MJ/ha)}$$

**Energy productivity (EP)**

$$EP = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Input energy } E_i\ (\text{MJ ha}^{-1})}$$

## Results and Discussion

**Production**

Based on the analysis of variance, both wheat grain and stover yield values were added for study at the 5% level of significance (Table 6). During both the years of study, zero tillage produced higher grain (5.06 t and 4.96 t) and stover yield (5.94t and 5.93t) than conventional tillage. Among wheat cultivars, DBW-187 was noted to produce significantly higher grain yield (5.13 t) and stover yield (6.06 t) in 2023-24 and about 4.93t grain yield and 5.98t stover yield during 2024-25 over HD-3226 and HD-3249. In nutrient management, significantly higher grain (5.21 t & 5.01 t) and stover yield (6.19 t & 6.07 t) values were found in 150% of NPK, followed by NPK 125% and NPK 100%. This might be due to improved soil physical conditions and buildup of organic carbon in ZT plots. Improved soil properties related to increased or maintain water holding capacity, better infiltration, root penetration and adequate nutrient supply. ZT recognized to create these congenial conditions. Such conditions are favored to better growth attributing and yield attributing characters and finally yield.

**Input Energy (MJha$^{-1}$)**

The tillage and nutrient management for wheat crop had a considerable effect on input energy, but wheat cultivars did not exert the significant effect (Table 7). The energy use of 21861.07 MJ/ha was significantly highest in conventional tillage (CT) over zero tillage (ZT) where 19524.56 MJ/ha energy was utilized. It was due to the high requirement of tillage, fuel, labour, sowing, fertilizers and irrigation in CT.

Similar findings were recorded by Nandan *et al.* (2021) and Parihar *et al.* (2017). Among wheat cultivars, input energy was remained similar for each cultivar (20692.82 MJ/ha) due to the equal amount of seed was used in treatments. In case of nutrient management, significantly input energy required to 150% NPK (22744.32 MJ/ha), followed NPK 125% (20692.82 MJ/ha) and NPK 100% (18641.32 MJ/ha). It was due to the higher amount of fertilizer was applied in 150% NPK than other and to produce higher amount of fertilizer required more energy.

### Output energy (MJha$^{-1}$)

During both years (2023-24 and 2024-25), output energy was higher under ZT wheat (148578.92 and 146244.77 MJ/ha, respectively) over CT wheat (137901.54 and 132774.25 MJ/ha). These results are matched with findings of Kumar *et al.* (2013) and Nandan *et al.* (2021). It was due to the higher yield obtained and lower energy input requirement in ZT wheat over CT wheat. Wheat cultivars and nutrient management exhibited considerable effect on energy output (Table 7). The significantly higher energy output was registered from DBW187 variety (151184.35 and 147242.14 MJ/ha during both years, respectively) and NPK 150% (153896.56 and 149632.03 MJ during both years, respectively) over rest of the varieties and NPK levels. It might be due to the higher grain and straw yield under DBW187 and NPK 150%.

**Table 3:** Fixed input energy calculation for conventional tillage wheat. (Work sheet)

| Constituents | Source of energy | Calculation | |
|---|---|---|---|
| **Common input energy** | | | |
| **1.** Pre-sowing irrigation | Diesel engine (5Hp) | $\frac{\text{Engine weight (kg)}}{\text{Life duration (hrs)}} \times \text{MJ} \times \text{hrs}$ | $\frac{165}{10500} \times 64.80 \times 12$ **=12.22 MJ** |
| | 2 Men labour | 2×8 hrs ×1.96 MJ | **=31.36 MJ** |
| | Diesel consumption (1.5 ltrs/hr) | For 12 hrs × 1.5 ltr × 56.31 MJ | **=1013.58 MJ** |
| **2.** Two cross ploughing by harrow (4 hrs ha$^{-1}$ for 2 ploughing) | Mechanical- tractor | $\frac{\text{Tractor weight (kg)}}{\text{Life duration (hrs)}} \times \text{MJ} \times \text{hrs}$ | $\frac{2400}{12000} \times 64.80 \times 8$ **=103.68 MJ** |
| | Harrow used | $\frac{\text{Harrow weight (kg)}}{\text{Life duration (hrs)}} \times \text{MJ} \times \text{hrs}$ | $\frac{433}{4000} \times 62.70 \times 8$ **=54.30 MJ** |
| | Diesel consumption (3ltr/hrs) | 3 × 8 × 56.31 MJ | **= 1351.44 MJ** |
| | Human to derive | 8hrs×1.96 MJ | **=15.68 MJ** |
| 3. Rotavator (2.5hrs/ha) for one ploughing) | Mechanical- tractor | $\frac{\text{Tractor weight (kg)}}{\text{Life duration (hrs)}} \times \text{MJ} \times \text{hrs}$ | $\frac{2400}{12000} \times 64.80 \times 2.5$ **=32.4** |
| | Rotavator used | $\frac{\text{Rotavator weight (kg)}}{\text{Life duration (hrs)}} \times \text{MJ} \times \text{hrs}$ | $\frac{433}{4000} \times 62.70 \times 2.5$ **=16.97 MJ** |
| | Diesel consumption (4ltr/hrs) | 4×2.5×56.31MJ | **=563.1 MJ** |
| | Human to derive | 2.5hrs × 1.96 MJ | **=4.9 MJ** |
| 4. Layout making | 2 Men labour | 2×8 hrs ×1.96 MJ | **=31.36 MJ** |
| 5. Making of bunds & irrigation channels by tractor drawn bund maker (1 hrs/ha) | Mechanical- tractor | $\frac{\text{Tractor weight (kg)}}{\text{Life duration (hrs)}} \times \text{MJ} \times \text{hrs}$ | $\frac{2400}{12000} \times 64.80 \times 1$ **=12.96 MJ** |
| | Bund maker | $\frac{\text{Bund maker weight (kg)}}{\text{Life duration (hrs)}} \times \text{MJ} \times \text{hrs}$ | $\frac{100}{4000} \times 62.70 \times 1$ **=1.57 MJ** |
| | Diesel consumption (3ltr/hrs) | 3 × 1 × 56.31 MJ | **=168.93** |
| | Human to derive | 1hrs×1.96 MJ | **=1.96 MJ** |
| 6. Seed treatment with fungicide (200g/100kg seed for one ha) | Bavistine 200 g | 0.2 kg × 120 MJ | **=24 MJ** |
| | 1 hrs men labour | 1hrs×1.96 MJ | **=196 MJ** |
| 7. Sowing by seed drill machine | Mechanical- tractor | $\frac{\text{Tractor weight (kg)}}{\text{Life duration (hrs)}} \times \text{MJ} \times \text{hrs}$ | $\frac{2400}{12000} \times 64.80 \times 2.5$ **=32.4 MJ** |

| | | | |
|---|---|---|---|
| (3hrs/ha) | Seed drill used | $\frac{\text{Seed drill used (kg)}}{\text{Life duration (hrs)}} \times MJ \times hrs$ | $\frac{400}{4000} \times 62.70 \times 2.5$ **=15.68 MJ** |
| | Diesel consumption (4ltr/hrs) | 4×3×56.31MJ | **=675.72 MJ** |
| | Human to derive | 3 hrs × 1.96 MJ | **=5.88 MJ** |
| 8. 4 Irrigation (12hrs/ha/irri.) | Diesel engine (5Hp) | $\frac{\text{Engine weight (kg)}}{\text{Life duration (hrs)}} \times MJ \times hrs$ | $\frac{165}{10500} \times 64.80 \times 48$ **=48.88 MJ** |
| | 2 Men labour/ irrigation | 8lbr × 8hrs× 1.96 MJ | **= 125.44 MJ** |
| | Diesel consumption (1.5 ltrs/hr) | For 48 hrs × 1.5 ltr × 56.31 MJ | **= 4054.32 MJ** |
| 9. Weed Management | Pendimethalin 30 EC (0.75 ltr/ha) | 0.75 ltrs× 120 MJ | **= 90 MJ** |
| | Labour for application | 3 Men × 8hrs × 1.96 MJ | **= 47.04 MJ** |
| | 1 manual weedings | 20 lbr × 8 hrs × 1.96 MJ | **=313.6 MJ** |
| 10. Harvesting & Threshing | Labour for harvesting | 20 women lbrs × 8 hrs × 1.57 MJ | **251.2 MJ** |
| | Threshing by tractor | $\frac{\text{Tractor weight (kg)}}{\text{Life duration (hrs)}} \times MJ \times hrs$ | $\frac{2400}{12000} \times 64.80 \times 3$ **= 38.88 MJ** |
| | Thresher used | $\frac{\text{Thresher (kg)}}{\text{Life duration (hrs)}} \times MJ \times hrs$ | $\frac{1000}{5000} \times 62.70 \times 3$ **=37.62 MJ** |
| | Diesel consumption (4 ltrs/hr) | For 3 hrs × 4 ltr × 56.31 MJ | **= 675.72 MJ** |
| | Labour for threshing, bagging & tagging | 10 women lbrs × 3hrs × 1.57 MJ | **= 47.1 MJ** |
| **Total** | | | **=10095.89 MJ** |

**Table 4:** Fixed input energy calculation for zero tillage wheat (Work sheet)

| Constituents | Source of energy | Calculation | |
|---|---|---|---|
| **Common input energy** | | | |
| **Field preparation** | | | |
| **1.** Pre-sowing irrigation | Diesel engine (5Hp) | $\frac{\text{Engine weight (kg)}}{\text{Life duration (hrs)}} \times MJ \times hrs$ | $\frac{165}{10500} \times 64.80 \times 12$ **=12.22 MJ** |
| | 2 Men labour | 2×8 hrs ×1.96 MJ | **=31.36 MJ** |
| | Diesel consumption (1.5 ltrs/hr) | For 12 hrs × 1.5 ltr × 56.31 MJ | **=1013.58 MJ** |
| 2. Layout making | 2 Men labour | 2×8 hrs ×1.96 MJ | **= 31.36 MJ** |
| 3. Making of bunds & irrigation channels by tractor drawn bund maker (1 hrs/ha) | Mechanical- tractor | $\frac{\text{Tractor weight (kg)}}{\text{Life duration (hrs)}} \times MJ \times hrs$ | $\frac{2400}{12000} \times 64.80 \times 1$ **=12.96 MJ** |
| | Bund maker | $\frac{\text{Bund maker weight (kg)}}{\text{Life duration (hrs)}} \times MJ \times hrs$ | $\frac{100}{4000} \times 62.70 \times 1$ **=1.57 MJ** |
| | Diesel consumption (3ltr/hrs) | 3 × 1 × 56.31 MJ | **= 168.93 MJ** |
| | Human to derive | 1hrs×1.96 MJ | **= 1.96 MJ** |
| 4. Seed treatment with fungicide (200g/100kg seed for one ha) | Bavistine 200 g | 0.2 kg × 120 MJ | **= 24 MJs** |
| | 1 hrs men labour | 1hrs×1.96 MJ | **= 1.96 MJ** |
| 5. Sowing by zero till machine (3hrs/ha) | Mechanical- tractor | $\frac{\text{Tractor weight (kg)}}{\text{Life duration (hrs)}} \times MJ \times hrs$ | $\frac{2400}{12000} \times 64.80 \times 2.5$ **= 32.4 MJ** |
| | Seed drill used | $\frac{\text{Seed drill used (kg)}}{\text{Life duration (hrs)}} \times MJ \times hrs$ | $\frac{400}{4000} \times 62.70 \times 2.5$ **= 15.68 MJ** |
| | Diesel consumption (4ltr/hrs) | 4×3×56.31MJ | **= 675.72 MJ** |

| | | | |
|---|---|---|---|
| | Human to derive | 3 hrs × 1.96 MJ | **= 5.88 MJ** |
| 6. 4 Irrigation (12hrs/ha/irri.) | Diesel engine (5Hp) | $\frac{\text{Engine weight (kg)}}{\text{Life duration (hrs)}} \times \text{MJ} \times \text{hrs}$ | $\frac{165}{10500} \times 64.80 \times 48$ **= 48.88 MJ** |
| | 2 Men labour/ irrigation | 8lbr × 8hrs× 1.96 MJ | **= 125.44 MJ** |
| | Diesel consumption (1.5 ltrs/hr) | For 48 hrs × 1.5 ltr × 56.31 MJ | **= 4054.32 MJ** |
| 7. Weed Management | Pendimethalin 30 EC (0.75 ltr/ha) | 0.75 ltrs× 120 MJ | **= 90 MJ** |
| | Labour for application | 3 Men × 8hrs × 1.96 MJ | **= 47.04 MJ** |
| | 1 manual weedings | 20 lbr × 8 hrs × 1.96 MJ | **=313.6 MJ** |
| 8. Harvesting & Threshing | Women Labour for harvesting | 20 lbrs × 8 hrs × 1.57 MJ | **= 251.2 MJ** |
| | Threshing by tractor | $\frac{\text{Tractor weight (kg)}}{\text{Life duration (hrs)}} \times \text{MJ} \times \text{hrs}$ | $\frac{2400}{12000} \times 64.80 \times 3$ **=38.88 MJ** |
| | Thresher used | $\frac{\text{Thresher (kg)}}{\text{Life duration (hrs)}} \times \text{MJ} \times \text{hrs}$ | $\frac{1000}{5000} \times 62.780 \times 3$ **=37.62 MJ** |
| | Diesel consumption (4 ltrs/hr) | For 3 hrs × 4 ltr × 56.31 MJ | **= 675.72 MJ** |
| | Labour for threshing, bagging & tagging | 10 women lbrs × 3hrs × 1.57 MJ | **= 47.1 MJ** |
| **Total** | | | **= 7759.38 MJ S** |

**Table 5:** Treatment wise input energy calculation for wheat

| **Constituents** | **Source of energy** | **Calculation** | |
|---|---|---|---|
| **A. Main Factor (Tillage)** | | | |
| 1. Conventional tillage | | **Total** | **=10095.89 MJ** |
| 2. Zero tillage | | **Total** | **=6702.22 MJ** |
| **B. Sub factor (Varieties)** | | | |
| 1. HD 3226 | 100 kg seed/ha | 100 kg× 14.7 MJ | **=1470 MJ** |
| 2. HD 3249 | 100 kg seed/ha | 100 kg× 14.7 MJ | **= 1470 MJ** |
| 3. DBW 187 | 100 kg seed/ha | 100 kg× 14.7 MJ | **= 1470 MJ** |
| C. **Sub- Sub factor** (Nutrient Management) | | | |
| 1. 100% NPK (120:60:40 kg/ha N:P:K) | | | |
| | 120 kg N | 120×60.60 MJ | =7272 MJ |
| | 60 kg P | 60 ×11.1MJ | =666 MJ |
| | 40 kg K | 40 ×6.7 | = 268 MJ |
| | 4 women lbrs for Two top dressings | 4× 6 hrs × 1.57 MJ | =37.68 MJ |
| | | **Total** | **=8243.68 MJ** |
| 2. 125 % NPK (150:75:50kg/ha N:P:K) | | | |
| | 150 kg N | 150×60.60 MJ | = 9090 MJ |
| | 75 kg P | 75 ×11.1MJ | =832.5 MJ |
| | 50 kg K | 50 ×6.7 | =335 MJ |
| | 4 women lbrs for Two top dressings | 4× 6 hrs × 1.57 MJ | =37.68 MJ |
| | | **Total** | **=10295.18 MJ** |
| 3. 150 % NPK (180:90:60 kg/ha N:P:K) | | | |
| | 180 kg N | 180×60.60 MJ | = 10908 MJ |
| | 90 kg P | 90 ×11.1MJ | =999 MJ |
| | 60 kg K | 60 ×6.7 | = 402 MJ |
| | 4 women lbrs for Two top dressings | 4× 6 hrs × 1.57 MJ | =37.68 MJ |
| | | **Total** | **= 12346.68 MJ** |

## Net energy gain/return (MJ/ha)

The highest net energy gain was received when the crop was sown under ZT (129054.36 and 126720.21 MJ/ha during 2023-24 and 2024-25, respectively) as compared to CT (116040.47 and 110913.18 MJ/ha) (Table 7). The ZT produced higher NEG (11.21 and 14.25 % during both years, respectively) over CT. Results are similar to the Hosseini *et al.* (2016). This is due the less input requirement and higher yield production in ZT. Wheat cultivars and nutrient management were expressed the significant effect on NEG during both years. Significant NEG was observed with DBW 187 (130491.54 and 126549.33 MJ/ha) and NPK 150% (131152.24 and 126887.72 MJ/ha), followed by remaining varieties and NPK levels. It might be due to higher yield production as compared energy investment in these treatments.

**Table 6:** Effect of tillage and nutrient management practices on grain yield and stover yield, of wheat cultivars

| Treatments | Grain yield (tha$^{-1}$) | | Stover yield (tha$^{-1}$) | |
|---|---|---|---|---|
| **Tillage methods** | **2023-24** | **2024-25** | **2023-24** | **2024-25** |
| T1: CT | 4.58 | 4.36 | 5.64 | 5.50 |
| T2: ZT | 5.06 | 4.91 | 5.94 | 5.93 |
| SEM± for Tillage | 0.12 | 0.13 | 0.10 | 0.11 |
| C.D.(0.05) | NS | NS | NS | NS |
| **Varieties (V)** | | | | |
| V1: HD3226 | 4.74 | 4.57 | 5.73 | 5.65 |
| V2: HD3249 | 4.59 | 4.40 | 5.58 | 5.51 |
| V3: DBW187 | 5.13 | 4.93 | 6.06 | 5.98 |
| SEM± for V | 0.09 | 0.10 | 0.11 | 0.08 |
| C.D.(0.05) | 0.31 | 0.32 | 0.35 | 0.27 |
| **Nutrient Management** | | | | |
| N1: 100% NPK | 4.44 | 4.26 | 5.40 | 5.33 |
| N2: 125% NPK | 4.82 | 4.63 | 5.79 | 5.73 |
| N3: 150% NPK | 5.21 | 5.01 | 6.19 | 6.07 |
| SEM± for NM | 0.13 | 0.06 | 0.11 | 0.07 |
| C.D.(0.05) | 0.38 | 0.18 | 0.33 | 0.20 |
| Interaction effect | NS | NS | NS | NS |

**Table 7:** Effect of tillage, nutrient management and wheat cultivars on input & output energy, net energy gain, energy ratio and, energy productivity

| **Treatments** | **Input energy (MJ ha$^{-1}$)** | | **Output energy (MJ ha$^{-1}$)** | | **Net energy gain (MJ ha$^{-1}$)** | | **Energy ratio** | | **Energy productivity (kg/MJ)** | |
|---|---|---|---|---|---|---|---|---|---|---|
| Tillage methods | **2023-24** | **2024-25** | **2023-24** | **2024-25** | **2023-24** | **2024-25** | **2023-24** | **2024-25** | **2023-24** | **2024-25** |
| T1: CT | 21861.07 | 21861.07 | 137901.54 | 132774.25 | 116040.47 | 110913.18 | 6.32 | 6.08 | 0.21 | 0.20 |
| T2: ZT | 19524.56 | 19524.56 | 148578.92 | 146244.77 | 129054.36 | 126720.21 | 7.63 | 7.51 | 0.26 | 0.25 |
| SEM± for Tillage | 45.36 | 45.36 | 2883.42 | 3291.46 | 2883.42 | 3291.46 | 0.12 | 0.16 | 0.01 | 0.01 |
| C.D.(0.05) | 276.01 | 276.01 | NS | NS | NS | NS | 0.73 | 0.97 | 0.03 | 0.04 |
| **Varieties (V)** | | | | | | | | | | |
| V1: HD3226 | 20692.82 | 20692.82 | 141321.66 | 137782.57 | 120628.84 | 117089.75 | 6.89 | 6.71 | 0.23 | 0.22 |
| V2: HD3249 | 20692.82 | 20692.82 | 137214.68 | 133503.82 | 116521.87 | 112811.01 | 6.68 | 6.50 | 0.22 | 0.21 |
| V3: DBW187 | 20692.82 | 20692.82 | 151184.35 | 147242.14 | 130491.54 | 126549.33 | 7.34 | 7.17 | 0.25 | 0.24 |
| SEM± for V | 55.56 | 55.56 | 2464.14 | 2410.56 | 2464.14 | 2410.56 | 0.12 | 0.12 | 0.00 | 0.00 |
| C.D.(0.05) | NS | NS | 8035.94 | 7861.21 | 8035.94 | 7861.21 | 0.39 | 0.39 | 0.02 | 0.02 |
| **Nutrient Management (N)** | | | | | | | | | | |
| N1: 100% NPK | 18641.32 | 18641.32 | 132718.53 | 129223.33 | 114077.21 | 110582.01 | 7.17 | 6.98 | 0.24 | 0.23 |
| N2: 125% NPK | 20692.82 | 20692.82 | 143105.61 | 139673.17 | 122412.79 | 118980.36 | 6.95 | 6.79 | 0.23 | 0.23 |
| N3: 150% NPK | 22744.32 | 22744.32 | 153896.56 | 149632.03 | 131152.24 | 126887.72 | 6.80 | 6.61 | 0.23 | 0.22 |
| SEM± for NM | 55.56 | 55.56 | 3143.04 | 1742.18 | 3143.04 | 1742.18 | 0.15 | 0.09 | 0.01 | 0.00 |
| C.D.(0.05) | 162.15 | 162.15 | 9173.79 | 5085.01 | 9173.79 | 5085.01 | NS | 0.25 | NS | NS |
| Interaction effect | NS | NS | NS | NS | 3484.82 | 3409.05 | NS | NS | NS | NS |

## Energy ratio

Energy input and output ratio was varied considerably across the experimental years by tillage and, varieties while by nutrient management energy ratio was remained unaffected in first year and in second influenced significantly (Table 7). The minimum energy ratio was reported under CT (6.32 and 6.08 during 2023-24 and 2024-25, respectively) as compared to ZT (7.63 and 7.51). These results are matched with findings of Sandeep Sahu (2024). It was due to low output received and higher input energy required in CT. Between wheat cultivars, significantly higher energy ratio was recorded for the DBW 187 (7.34 and 7.17), followed by HD 3226 (6.89 and 6.71) and HD 3249 (6.68 and 6.50) because DBW 187 produced higher yield over others. Among nutrient management, maximum energy ratio was obtained with NPK 100% (7.17 and 6.98), followed by NPK 125% (6.95 and 6.79) and NPK 150% (6.80 and 6.61).

## Energy productivity

The energy productivity (kg/ha) markedly varied across the investigation period due to tillage and wheat cultivars (Table 7). However nutrient management exhibited non-significant effect on energy productivity during both the years. The significantly highest energy productivity was received under ZT wheat (0.26 and 0.25 during both cropping years, respectively) as compared to CT wheat (0.21 and 0.20). This might be due to production of more yields in ZT plots and less expenditure involved in production with saving of natural resources of higher values. Similar results were had been reported by Moradi *et al.* (2018) and Parihar *et al.* (2022). In cultivars, energy productivity was found considerably higher with DBW 187 (0.25 and 0.24 kg/MJ) over others. Under nutrient management, maximum energy productivity (0.24 and 0.23 kg/MJ) was registered in NPK 100%, followed by NPK 125% and NPK 150%.

## Conclusion

On the basis of results, it may be concluded that tillage and nutrient management practices exhibited the significant influence on the energy consumption. Total energy consumption was less and net energy gain was higher in zero tillage. Net energy return was also significantly higher in wheat cultivar DBW 187 and nutrient level 150% NPK over others treatments. The energy ratio was computed significantly higher in zero tillage, DBW 187 and NPK level 100% amongst the establishment methods, varieties and nutrient levels, respectively. The energy productivity was found significantly higher in zero tillage among tillage practices, DBW 187 among varieties but it was found higher in 100% NPK level over 125% and 150% NPK levels. It indicated that the zero-tillage wheat could be sustainable in terms of energy saving, energy ratio and energy productivity under rice-wheat cropping system.

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