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Research Paper

Productivity and energy use efficiency of wheat (*Triticum aestivum*) genotypes under different tillage options in rainfed ecosystem of middle Indo-Gangetic Plains

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ABSTRACT

A field experiment was conducted during the winter seasons of 2013–14 and 2014–15 at Patna, Bihar, to assess the productivity of 5 promising genotypes 'K 9351', 'K 7903', 'HD 2967', 'DBW 14' and 'HI 1563' of wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] under 2 tillage systems (no-till and conventional tillage). No-till (NT) resulted in grain yield on a par with conventional tillage (CT). Among the wheat genotypes, 'K 7903' gave significantly higher grain yield under both NT (3.4 t/ha) and CT (3.46 t/ha), followed by 'HD 2967' owing to better growth, yield attributes and physiological parameters than the other genotypes. Higher grain yields of 'K 7903' and 'HD 2967' under both tillage systems were directly correlated to their better leaf chlorophyll retention and maintenance of higher photosynthetic rate during grain-filling period. The maximum net income (₹19,687/ha) and benefit: cost ratio (1.71) were recorded with NT. Among wheat genotypes, 'K 7903' had significantly highest net income (₹26,759/ha) and benefit: cost ratio (1.92). Significantly higher energy ratio (8.43), energy profitability (6.0 MJ/kg) and energy-output efficiency (1015.6 MJ/ha/day) were recorded under NT than CT. Among the genotypes, 'K7903' was the most energy efficient than rest of the cultivars. Hence, growing of wheat genotypes 'K 7903' and 'HD 2967' under NT system proved better option in obtaining the maximum productivity, profitability and energy efficiency in middle Indo-Gangetic Plains.

Key words: Conventional tillage, Economics, Energetics, No-till, Wheat genotype, Yield

Rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L.) cropping is a predominant system in the middle Indo-Gangetic Plains (IGP). Sowing of wheat is always influenced by preceding rice crop, and mostly delayed due to the late harvesting of preceding crop of long-duration rice, resulting in lower yield. Tomar *et al.,* (2014) reported reduction in wheat yield to the tune of 38 to 76 kg/ha/day, when sown after 14 November. With the introduction of short-duration and drought-tolerant rice varieties and popularization of the no-till (NT) technology, it has become possible to plant wheat in time, especially in drought-prone rainfed areas of middle IGP. Use of resource-conservation technologies like NT in wheat is gaining popularity in rice–wheat cropping system of the middle IGP. This technology saves time, energy, cost of production, and helps in improving the soil health by increasing soil carbon status (Mondal *et al.*, 2016). It also improves the efficiency of fertilizer and reduces wear and tear on tractor. Significant differences exist among genotypes for morphological and physiological characters, which indicate availability of sufficient genetic variability for selection. Physical, chemical and biological changes induced by no-till systems are perhaps large enough to introduce genotype and environment interaction (G×E). Role of morpho-physiological plant traits for their adaptation under NT have remained largely unexplored since beginning and therefore, if explored can provide much-needed stimulus for the next big jump in yield (Gregory and George, 2011).

Wheat genotypes vary significantly in response to crop establishment (Kharub *et al.,* 2008). Hall and Cholick (1989) reported a significant genotype and tillage interaction for grain yield, indicating selecting suitable cultivars under NT may be beneficial for systems. So far, no wheat

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cultivar has been developed specifically for NT system. Varieties already developed for CT system are being used under NT too. It is still doubtful that cultivars yielding better in CT can also do well in NT system too. Hence present study was conducted to evaluate the performance of various wheat varieties under different tillage options in middle IGP.

MATERIALS AND METHODS

The field experiment was conducted during the winter seasons 2013–14 and 2014–15 at ICAR Research Complex for Eastern Region, Patna (25°30' N, 85°15' E, 52 m above mean sea-level. The soil at experimental site was clay loam (42.5% sand, 34.9% silt and 22.6% clay), low in organic carbon (0.48%) and nitrogen (218 kg N/ha), and medium in available phosphorus (22.3 kg P_2O_5/ha) and potassium (213 kg K_2O/ha). During the cropping season (November–April), monthly mean of minimum and maximum temperature ranged between 10.1°C–21.9°C and 18.8°C - 37.8°C, respectively. Total rainfall received during the cropping period was 106.2 and 44 mm in 2013–14 and 2014–15, respectively (Fig. 1). Five wheat genotypes viz. 'K 9351', 'K 7903', 'HD 2967', 'DBW 14' and 'HI 1563', were evaluated under No-till (NT) and conventional tillage (CT) systems. The details of wheat genotypes are given in Table 1. Experiment was laid-out in a split-plot design and replicated thrice. Two tillage systems (NT and CT) were kept in main-plots, whereas wheat genotypes in sub-plots. Under NT, sowing was done directly in anchored rice stubbles without any field preparation with the help of zero-till seed-cum-fertilizer drill, while in CT the field was prepared with ploughing once with mould board plough followed by 2 harrowing. The field was levelled with PATA (moving heavy wooden plank) before wheat sowing. A seed rate of 125 kg/ha was used for sowing in both the tillage operations. The row spacing was 22.5 cm. The seeds were treated with fungicide Vitavex at 2.0 g/kg seed before sowing. The gross plot size was 24 m^2 and net plot size 20.16 m^2. The crop was fertilized with 80, 30, 20 and 25 kg/ha of N, P_2O_5, K_2O and $ZnSO_4$. Nitrogen was applied in two splits i.e. half as basal and remaining half at 25 days after sowing (DAS). While phosphorus, potash and zinc were applied basal. Only 1 supplemental irrigation was applied at crown-root initiation (CRI) stage. The field was kept weed-free as much as possible, especially early in season through hand-weeding twice. All the growth and yield attributes, viz. plant height, total number of tillers/m^2, effective tillers/m^2, dry-matter production, spike length, numbers of grains/spike and 1,000-grain weight, were recorded at maturity from ran-

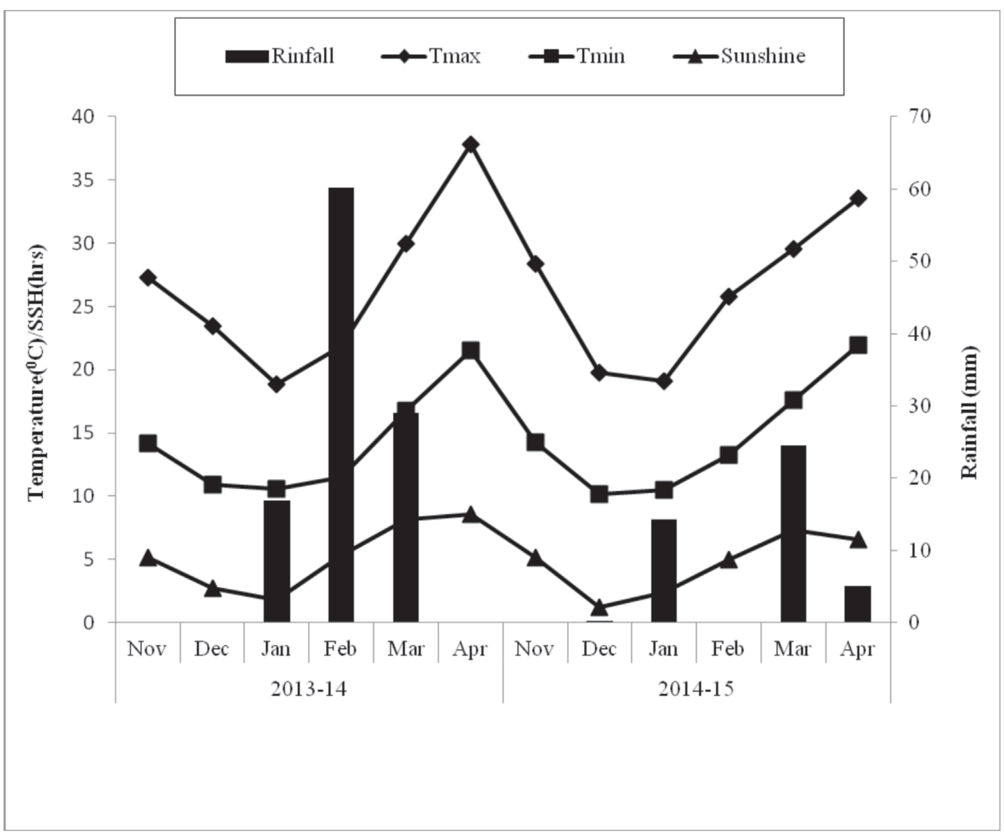

Fig. 1. Weather parameters during the experimentation

Table 1. Characterizations of the wheat genotypes used for the trials

Varieties	Pedigree	Year of release	Place of release	Plant height (cm)	Maturity duration (days)	Grain characters
'K 9351' (Mandakini)	K 72 / K 8027/ K 72	2005	CSAUAT, Kanpur	95–100	115–120	Amber coloured, hard textured
'K 7903' (Halna)	HD 1982 / K 816	2002	CSAUAT, Kanpur	80–85	120–125	Amber coloured, hard textured, ovate shaped and medium in size
'HD 2967' (Pusa Sindhu Ganga)	ALD/COC//URESH/ HD 2160M/HD 2278	2011	IARI, New Delhi	95–100	125–130	Amber coloured, hard textured, ovate shaped
'DBW 14'	RAJ 3765/PBW 343	2003	DWR, Karnal	75–80	110–115	Amber and hard grains
'HI 1563' (Pusa Prachi)	MACS 2496*2/MC 10	2011	IARI, RS, Indore	80–85	120–125	Amber and hard grains

CSAUAT, Chandra Shekhar Azad University of Agriculture and Technology; IARI, Indian Agricultural Research Institute; DWR, Directorate of Wheat Research

domly selected hills in each plot as per standard procedures.

The root length, shoot length and leaf-area index (LAI) were recorded at 75 DAS. Relative water content (RWC) was estimated by recording turgid weight of 0.5 g fresh leaf sample by keeping in water for 4 hr, followed by drying in hot air oven till constant weight is achieved (Weatherly, 1950). Membrane-stability index (MSI) was estimated as suggested by Sairam *et al.* (1997). The chlorophyll content was measured at 75 DAS as per the procedure given by Hiscox and Israelstam (1979) and was expressed as mg/g dry weight. Rate of photosynthesis was measured on fully expanded flag leaves using portable Infrared Gas Analyzer (IRGA LI-6400 Model, LICOR, USA) and expressed as μmol/m^2/s. Economics of wheat was calculated based on minimum support price (MSP) declared by the Government of India. Net income was calculated as difference between gross income and cost of cultivation. Benefit: cost ratio was worked out by dividing gross returns with cost of cultivation. The crop productivity (kg/ha/day) and economic efficiency (₹/ha/day) were calculated as per Kumawat *et al.* (2012). The economic yield of crops was converted into equivalent value of carbohydrate (t/ha) as suggested by Gopalan *et al.* (2004). Energy fluxes of crop were estimated using crop management (machinery operations and amount of input used) and biomass production records. To study the energy inputs and outputs of individual cropping, a complete inventory of all the crop inputs (fertilizers, seeds, plant-protection chemicals, fuels, human labour and machinery power) and outputs of both main and by-products was taken into the account. Energy value of wheat was determined based on energy inputs and energy production. Input and output were converted from physical to energy unit measures through published conversion of coefficients (Devasenapathy *et al.*, 2009; Tuti *et al.*, 2012; Sorokhaibam *et al*., 2016; Negi *et al*., 2016).

Input energy:

Energy equivalents for all inputs were summed to provide an estimate for total energy input.

Output energy:

The biomass crop yield is the yields of grain and by-product (straw). Energy output from the product (grain) was calculated by multiplying the amount of production and its corresponding energy equivalent. Energy output from the by-product (straw) was estimated by multiplying the amount of by-product and its corresponding equivalent.

Net energy return:

It is the difference between the gross output energy produced and the total energy required to obtain it (input energy).

$$\text{Energy ratio (ER)} = \frac{\text{Output energy (MJ/ha)}}{\text{Input energy (MJ/ha)}}$$

$$\text{Energy profitability (PE)} = \frac{\text{Net energy return (MJ/ha)}}{\text{Input energy (MJ/ha)}}$$

$$\text{Human energy profitability (HPE)} = \frac{\text{Output energy (MJ/ha)}}{\text{Labour energy (MJ/ha)}}$$

$$\text{Energy productivity (EP)} = \frac{\text{Crop economic yield (kg/ha)}}{\text{Energy input (MJ/ha)}}$$

$$\text{Energy intensiveness (EI)} = \frac{\text{Energy input (MJ/ha)}}{\text{Cost of cultivation Rs(MJ/ha)}}$$

$$\text{Energy intensity in physical terms (MJ/kg)} = \frac{\text{Total input (MJ/ha)}}{\text{Total output (kg) (grain+straw)}}$$

$$\text{Energy intensity in economic terms (MJ/₹)} = \frac{\text{Gross energy output}}{\text{Cost of cultivation (₹/ha)}}$$

The field data obtained for 2 years were pooled and statistically analysed using the F-test (Gomez and Gomez, 1984).Test of significance of the treatment differences were done on the basis of t-test. Significant difference between treatment means were compared with critical differences at 5% levels of probability.

RESULTS AND DISCUSSION

Growth attributes

The data on germination (%) and growth attributes, i.e. plant height, total number of tillers/m^2, effective tillers/m^2, dry-matter production, spike length and grains/spike, 1,000-grain weight, were markedly influenced with tillage systems (Table 2). The germination percentage did not differ significantly due to various tillage systems. Significantly higher plant height was recorded under NT as compared to CT. Among the genotypes, the maximum plant height was recorded with 'K 7903' and minimum with 'DBW 14'. Total number of tillers/m^2 and effective tillers/m^2 were higher with NT than with CT. Among the genotypes, the highest number of total tillers/m^2 was recorded with 'HD 2967', followed by 'K 7903', whereas the highest number of effective tillers was recorded with 'K 7903', followed by 'HD 2967'. The maximum dry matter at maturity was produced by 'K 7903', which was statistically similar to 'HD 2967'. The minimum dry matter was recorded in 'DBW 14'. Significantly higher root length was recorded in NT than CT. Trethowan *et al.* (2005) also reported improved root health and enhanced nutritional value of grain with NT. No significant difference was observed for shoot length between NT and CT. Among the genotypes, maximum root and shoot length was recorded with 'K 7903' (Table 3).

Physiological attributes like leaf-area index (LAI), relative water content RWC, (%), membrane-stability index (MSI %), chlorophyll content and photosynthesis rate were higher with NT than with CT (Table 3). The maximum LAI was recorded with 'K 7903', which was at par with 'HD 2967'. No significant difference was observed between tillage systems in respect of RWC (%) and MSI (%). Dwivedi *et al*. (2013) also reported that higher genotypic differences in wheat in terms of RWC, MSI, chlorophyll and photosynthetic rate under moisture-stress condition. Significantly higher chlorophyll content was recorded under ZT than with CT. The highest chlorophyll content was recorded with 'K 7903' followed by 'HD 2967'. Irrespective of tillage systems, the highest photosynthetic rate was observed with 'K 7903' followed by 'HI 1563'. However, the lowest rate of photosynthetic rate was recorded with 'DBW 14'. This might be due to increase in chlorophyll content *vis* correlated with an increase in the net photosynthetic rate (Ibrahim *et al*., 2011).

Yield attributes and yield

The yield attributes such as spike length and 1,000-grain weight were higher with NT than with CT. Conventional sowing of wheat resulted in higher number of grains/spike, which was at par with NT (47.4). Irrespective of tillage systems, the maximum spike length was recorded in 'K 7903', which was on a par with 'HD 2967'. Among the genotypes, number of grains/spike was higher with 'HD 2967' followed by 'K 7903', and 'K 9351', which were at par with each other. Similarly, 1,000-grain weight was higher in 'HD 2967' followed by 'K 7903' and 'K 9351', being at par with each other. The mean grain,

Table 2. Effect of tillage systems on growth and yield attributes of wheat genotypes (pooled data of 2 years)

Treatment	Germination (%)	Plant height (cm)	Total tillers/m^2	Effective tillers/m^2	Spike length (cm)	Number of grains/ spike	1,000-grain weight (g)	Dry matter (g/m^2) at maturity
Establishment method								
No-till	86	90.3	356.7	299.7	8.11	47.4	39.4	1,081
Conventional tillage	85	88.8	338.9	282.4	8.06	48.1	38.2	1,149
SEm±	0.6	0.4	13	11	0.3	1.6	0.31	31
CD (P=0.05)	NS	1.2	NS	NS	NS	NS	0.86	NS
Genotypes								
'K 9351'	84	98.3	313.9	252.4	7.78	49.1	39.1	1,054
'K 7903'	86	99.3	379.2	320.1	8.56	49.6	39.9	1,245
'HD 2967'	87	91.1	397.6	296.6	8.33	51.9	40.1	1,207
'DBW 14'	83	73.4	319.2	302.3	7.81	42.9	37.5	996
'HI 1563'	87	85.8	329.4	283.9	7.96	45.3	37.7	1,102
SEm±	0.9	1.1	12	14	0.21	2.03	0.48	35
CD (P=0.05)	2.8	2.9	35	39	0.58	6.12	1.53	104

straw and biological yields of different varieties did not vary significantly under different tillage options (Table 4). The grain yield difference of CT over NT was 4.28%. Irrespective of tillage systems, the maximum grain yield was found in ‘K 7903’, which was at par with that recorded ‘HD 2967’. It was probably owing to higher growth and yield attributes caused by better nutrient absorption from soil, increased rate of metabolic process, rate of light absorption and increased rate of photosynthetic activity compared to the other genotypes. The straw yield (5.20 t/ha) and biological yield (8.44 t/ha) were found significantly higher in ‘HD 2967’ followed by ‘K 7903’ (4.83 t/ha, 8.26 t/ha). In respect of tillage system, the maximum grain yield of 3.41 t/ha and 3.46 t/ha was recorded in wheat genotype ‘K 7903’ under NT and CT, respectively (Table 5). For better grain yield, higher number of effective tillers, spike length and 1,000-grain weight could possibly be the reason of the highest yield of ‘K 7903’ than the other genotypes tested. However, the lowest grain yield of 2.43 t/ha and 2.44 t/ha was recorded with ‘DBW 14’ under NT and CT, respectively. Most of genotypes except ‘HD 2967’ recorded higher grain yield under CT condition than NT. The crop productivity was markedly influenced by cultivars (Table 4). Significantly higher crop productivity was recorded with wheat genotype ‘K 7903’ (34.12 kg/ha/day) over rest of the cultivars. This might be owing to more grain yield produced with the genotype. Further, economic yield of wheat was converted into equivalent value of carbohydrate (Table 4) and results revealed genotypes ‘K 7903’ (3,051 kg/ha) recorded significantly higher values followed by ‘HD 2967’ (2,820 kg/ha) and ‘HI 1563’ (2,384 kg/ha).

Table 3. Response of physiological attributes of wheat genotypes at anthesis stage under different tillage system (pooled data of 2 years)

Treatment	Root length (cm)	Shoot length (cm)	Leaf-area index	RWC (%)	MSI (%)	Chlorophyll content (mg/g DW)	Photosynthesis rate (μmol/m²/s)
Establishment method							
No-till	15.7	61.5	3.14	72	59	3.41	15.9
Conventional tillage	14.2	59.4	2.98	69	57	2.99	14. 6
SEm±	0. 22	1.2	0.17	1.3	0.8	0.13	0.27
CD (P=0.05)	0.69	NS	NS	NS	NS	0.37	1.14
Genotypes							
‘K 9351’	14.8	65.7	2.91	71	56	2.9	15.2
‘K 7903’	15.7	66.7	3.37	76	59	3.8	18.6
‘HD 2967’	15.4	49.9	3.21	69	61	3.5	16.1
‘DBW 14’	13.9	56.1	2.82	65	54	2.6	14.3
‘HI 1563’	14.9	63.7	3.01	72	60	3.3	16.4
SEm±	0.21	0.9	0.15	1.4	0.6	0.14	0.34
CD (P=0.05)	0.64	2.9	0.43	3.8	2.3	0.39	1.21

RWC, Relative water content; MSI, membrane stability index

Table 4. Response of yield, yield attributes and economic analysis of wheat genotypes under different tillage system (pooled data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index	Crop productivity (kg/ha/day)	Gross returns (×10³₹/ha)	Net returns (×10³₹/ha)	Crop profitability (₹/ha/day)	Benefit: cost ratio	Carbohydrate equivalent (kg/ha)
Establishment method										
No-till	2.90	4.62	7.53	0.39	30.05	46.8	19.7	178	1.71	2547
Conventional tillage	3.03	4.72	7.75	0.39	26.85	48.9	17.3	159	1.55	2447
SEm±	0.05	0.11	0.17	0.03	0.62	1.01	0.76	3.5	0.12	54.3
CD (P=0.05)	NS	NS	NS	NS	NS	NS	2.05	NS	NS	NS
Genotypes										
‘K 9351’	2.81	4.34	7.16	0.39	26.73	45.2	16.8	152	1.59	2289
‘K 7903’	3.43	4.83	8.27	0.42	34.12	55.1	26.8	226	1.92	3051
‘HD 2967’	3.23	5.21	8.45	0.38	31.45	52.9	24.5	199	1.86	2820
‘DBW 14’	2.44	4.42	6.85	0.36	22.85	39.1	10.8	104	1.26	1941
‘HI 1563’	2.93	4.56	7.48	0.39	27.10	46.9	18.6	163	1.65	2384
SEm±	0.06	0.21	0.24	0.01	0.43	1.28	0.82	2.46	0.02	38.2
CD (P=0.05)	0.22	0.59	0.61	0.03	1.28	3.54	2.38	7.39	0.05	114.6

Interaction effect between tillage and genotypes on grain yield was found to be significant (Table 5). Wheat cultivar 'HI 1563' gave the highest grain yield under CT as compared to NT, however, yield of the other cultivars did not vary significantly due to variation in tillage options. Kharub *et al.* (2008) also observed differences in genotypes with respect to grain yield and root biomass in different tillage options.

Economics

The maximum gross income was recorded with CT. However, net income and benefit: cost ratio (B:C) were recorded with NT, which were found to be significantly higher than CT (Table 4). The NT resulted in 12.1% higher net income over CT. Though conventional sowing of wheat fetched higher gross returns than NT but net returns and benefit: cost ratio reversed for them because of more cost of investment required in conventional sown wheat than NT. Bohra and Kumar (2015) also reported similar results. Among the wheat genotypes, 'K 7903' recorded significantly the highest gross returns and net income and benefit: cost ratio, followed by 'HD 2967'. Wheat genotype 'DBW 14' had the lowest gross returns, net returns and benefit: cost ratio because of its lower yield with respective genotypes. Sale prices of produce for different genotypes were the same, thus, difference in net income was largely due to variation in yield and crop management. Significantly higher crop profitability was noted with wheat genotypes 'K 7903' over rest of the cultivars. This might be owing to higher net returns attained by respective genotypes.

Table 5. Interaction effect of tillage systems and genotypes on grain yield (pooled data of 2 years)

Wheat genotypes	Grain yield (t/ha)		
	No-till	Conventional tillage	Mean
'K 9351'	2.72	2.91	2.81
'K 7903'	3.41	3.46	3.43
'HD 2967'	3.28	3.17	3.23
'DBW 14'	2.43	2.44	2.44
'HI 1563'	2.69	3.18	2.93
Mean	2.90	3.03	2.97
CD (P=0.05)	Tillage : NS,	Genotypes : 0.135,	T × G: 0.191, G × T : 0.261

Energetics

Comparison of energy-use pattern (Table 6) in different crop tillage systems revealed that the highest input energy was consumed under CT compared to NT. The highest input energy consumption under CT was due to more traction operation with the respective treatments (Bohra and Kumar, 2015). However, output energy and net energy

Table 6. Energy input-output relationship of genotypes with different crop establishment methods

Treatment	Input energy ($\times 10^3$ MJ/ha)	Output energy ($\times 10^3$ MJ/ha)	Net energy ($\times 10^3$ MJ/ha)	Energy ratio	Energy profitability (MJ/ha)	Human energy profitability	Energy productivity (kg/MJ)	Energy intensiveness (MJ/₹/ha)	Energy output efficiency (MJ/ha/day)	Energy intensity in physical terms (MJ/kg)	Energy intensity in economic terms (MJ/₹)
Establishment method											
No-till	14.3	120.8	86.0	8.43	6.00	117.0	0.249	0.483	1015.6	1.611	8.43
Conventional tillage	16.3	116.9	79.6	7.16	4.88	99.5	0.210	0.524	915.6	1.880	7.16
SEm±	-	2.68	1.88	0.18	0.13	2.47	0.005	-	15.2	0.043	0.18
CD (P=0.05)	-	NS	NS	1.09	0.76	15.06	0.031	-	92.7	0.261	1.09
Genotypes											
'K 9351'	15.3	106.1	73.3	6.95	4.82	96.4	0.211	0.504	881.5	1.936	6.95
'K 7903'	15.3	135.4	96.0	8.89	6.33	123.7	0.281	0.504	1078.4	1.529	8.89
'HD 2967'	15.3	129.5	88.6	8.51	5.82	118.0	0.260	0.504	1029.0	1.595	8.51
'DBW 14'	15.3	109.2	76.0	7.16	4.98	99.3	0.179	0.504	915.1	1.864	7.16
'HI 1563'	15.3	114.0	80.1	7.47	5.25	103.6	0.219	0.504	923.9	1.800	7.47
SEm±	-	1.84	1.28	0.12	0.08	1.67	0.003	-	22.1	0.028	0.12
CD (P=0.05)	-	5.52	3.85	0.36	0.25	5.00	0.010	-	66.3	0.084	0.36

Table 7. Traction power, time and fuel consumption and saving, CO_2 emission and consumption of equivalent energy of wheat under different crop establishment methods

Parameters	Crop-establishment methods	
	No-till	Conventional tillage
Tractor operation (no. of pass)	1	3
Time (h)	4	12
Fuel consumption (*l*)	14	42
Fuel saving (%)	200	-
Time saving (%)	200	-
CO_2 emission (kg/ha)	31.2	109.2
Reduction in CO_2 emission (%)	250	-
Consumption of equivalent energy (MJ/ha)	788	2,365
Reduction in consumption equivalent energy (%)	200	–

were noted higher with NT as compared to CT. Significantly higher energy ratio, energy profitability, human energy profitability, energy productivity, energy output efficiency and energy intensity in economic terms (8.43 MJ/Rs.) were significantly higher with NT compared to CT. The energy effectiveness and energy intensity in physical terms were markedly higher under CT over NT. This might be owing to higher energy-use efficiency under the particular crop-establishment methods was mainly attributed to higher energy production with the use of relatively lesser energy utilization.

With respect to wheat genotypes, output energy, net energy, energy ratio, energy profitability, human energy profitability, energy productivity, energy output efficiency and energy intensity in economic terms were significantly higher with 'K 7903' amongst the tested genotypes of wheat. However, energy intensity in physical terms was recorded markedly higher with 'K 9351' followed by 'DBW 14' and 'HI 1563'. The higher energy-use efficiency of wheat genotypes was mainly attributed to higher yield production with use of lesser energy utilization (Maurya *et al.,* 2014).

Comparison of traction power, time, fuel and time saving, CO_2 emission and consumption of equivalent energy use pattern in different tillage system of wheat (Table 7) revealed that the maximum traction power (3), time (12 h) and fuel consumption (42 *l*), CO_2 emission (109.2 kg) and consumption of equivalent energy use (2,365 MJ) were required under CT. However, the lowest traction power (1), time (4 h), fuel consumption (14 *l*), CO_2 emission (31.2 kg) and consumption of equivalent energy (788 MJ/ha) were consumed under NT. In respect to reduction in fuel, time, CO_2 emission and consumption equivalent energy (%), NT saved 250, 200, 250 and 200% as compared to CT. Bohra and Kumar (2015) was also reported similar findings.

Hence, growing of wheat genotypes 'K 7903' and 'HD 2967' under NT condition is a better option to obtain the maximum productivity, profitability and energy efficiency in middle Indo-Gangetic Plains.

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