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Optimization of energy use by tillage and weed management practices in wheat

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Abstract
The field experiments was conducted during *kharif* season of 2012-13 and 2013-14 at N.E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (Uttarakhand) India to find out the effect of different tillage practices and weed management practices on energy analysis (input-output) of wheat. The result revealed that energy consumption in terms of energy input was recorded maximum under conventional tillage with weed free situation (21704 MJ.ha-1) and the lowest energy input was recorded under zero tillage with weedy (19021 MJ.ha-1) which was followed by zero tillage with sulfosulfuron 25g/ha. Energy output, net energy return and energy use efficiency was maximum in case of zero tillage plots which was closely followed by application of pinoxaden 50g/ha fb MSM 4g/ha, readymix application of clodinofop 60g + MSM 4g/ha and clodinofop 60g fb MSM 4g/ha. Energy intensity was the lowest under zero tillage condition (3.4 MJ/kg)

Keywords: Energy use efficiency, energy intensity, wheat, tillage, weeds

Introduction
The rice–wheat system is one of the world's largest agricultural production systems, covering an area of 26 million ha, spread over the Indo-Gangetic Plains in South Asia (about 12.37 million ha) and China (Balasubramanian *et al.*, 2012) [1]. Wheat is an important Rabi crop of India, contributing towards food security to a large extent. Wheat is grown in an area of around 30 million hectares with a production of 93.50 million tons in India under diverse agroecological condition (Anonymous, 2016) [2]. Energy has been a key input of agriculture since the age of subsistence agriculture. It is an established fact worldwide that agricultural production is positively correlated with energy input (*TaheriGaravand et al., 2010*) [3]. Agriculture is both a producer and consumer of energy. Energy input–output analysis is usually used to evaluate the efficiency and environmental impacts of production systems (*Ozkan et al., 2004*) [4]. Energy use in agriculture has been increasing in response to increasing population, limited supply of arable land, and a desire for higher standards of living (Kizilaslan, 2009) [5]. In modern agriculture system input energy is very much higher than in traditional agriculture system, but energy use efficiency has been reduced in response to no affective use of input energy. Efficient use of energies helps to achieve increased productivity and contributes to the economy, profitability and competitiveness of agriculture sustainability in rural areas (Singh *et al*., 2002) [6]. The main objective of this study is analysis of energy use and energy intensity of wheat production under different tillage methods.

Material and Methods
The field experiments was conducted during *kharif* season of 2012-13 and 2013-14 at N.E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (Uttarakhand) India to find out the effect of different tillage practices and weed management practices on weed, wheat energy consumption. The soil of the experimental plot was loamy in texture. The soil of the experimental plot was medium in organic carbon, low in available nitrogen, medium in phosphorus and potassium contents with neutral pH. The experiment was conducted in split plot design with three replication; keeping the tillage practices *viz.*, Zero tillage (ZT), Reduced tillage (RT) and Conventional tillage (CT) in main plots and six levels of weed management practices *viz.*, Sulfosulfuron 25g/ha, ready mix of clodinafop-propargyl 15% + metsulfuron methyl 1% @ 64 g/ha, clodinafop-propargyl @ 60 g/ha FB Metsulfuron methyl 4g/ha, Pinoxaden 50g /ha FB Metsulfuron methyl 4g/ha weed free and weedy in sub plots.

Total energy input and output in wheat production systems was estimated by using energy equivalent of different inputs and outputs. Basic information on energy inputs and wheat yield (grain and straw) were entered into Excel spreadsheets and then energy indicators were calculated according Table 1. Finally input energy, output energy, energy use efficiency, net energy and energy intensity were determined applying standard equations. The experimental data were analysed online by using standard procedure for split plot design with the help of computer statistical programme OPSTAT programmed and developed by Department of Mathematics Statistics, CCS HAU, Hisar.

Energy use efficiency = (output energy ($MJ.ha^{-1}$)) / (input energy ($MJ.ha^{-1}$])

Energy intensity = (input energy ($MJ.ha^{-1}$)) / (wheat yield ($kgha^{-1}$))

Net energy returns = output energy ($MJ.ha^{-1}$) – input energy ($MJ.ha^{-1}$)

Table 1: Energy equivalents for input and output of wheat production systems

Sl. No.	Particulars	Unit	Energy equivalent (MJ/unit)
Input			
1.	Human labour	hr	1.96
2.	Machinery	hr	62.7
3.	Diesel fuel	L	56.31
4.	Chemical fertilizers Nitrogen (N) Phosphate (P_2O_5) Potassium (K_2O)	kg	 66.14 12.44 11.15
5.	Chemicals	kg	120
6.	Water for irrigation	m^3	1.02
Output			
1.	Wheat grain	kg	14.7
2.	Wheat straw	kg	12.5

Results and Discussions

Energy consumption and intensity are indicators of agricultural sustainability in the face of fossil energy scarcity and price volatility. The energy consumption in terms of energy input was recorded the maximum under conventional tillage with weed free situation and the lowest energy input was recorded under zero tillage with weedy which was closely followed by zero tillage with sulfosulfuron. Higher energy consumption in conventional tillage with weed free situation was because of more energy incurred in land preparation and sowing. Energy output and net energy return was found to be the maximum in the zero tillage with weed free condition followed by pinoxaden 50g/ha fb MSM 4g/ha, readymix application of clodinofop 60g/ha + MSM 4g/ha and clodinofop 60g/ha fb MSM 4g/ha due to higher grain and straw yield in these treatments. The lowest energy output was recorded under conventional tillage when weeds were not controlled as grain and straw yields were negatively affected by heavy weed infestation Energy use efficiency was the maximum in case of zero tilled plots where crop was kept weed free followed by herbicides combinations of pinoxaden 50g/ha fb MSM 4g/ha, readymix application of clodinofop 60g/ha + MSM 4g/ha and clodinofop 60g/ha fb MSM 4g/ha (Table 2). This is resulted from higher energy output and lower energy input in these treatment combinations. Energy use efficiency in general was low when crop was raised with conventional tillage. Kumar *et al*., 2013 [7] also reported the similar finding.

Energy intensity was lowest under zero tillage with weed free condition followed by readymix application of clodinofop 60g/ha + MSM 4g/ ha, pinoxaden 50g/ha fb MSM 4g/ha and clodinofop 60g/ha fb MSM 4g/ha due to higher grain and straw yield in these treatments under the same tillage practices. Energy intensity was highest where weeds were not managed in each establishment method as grain yield was reduced to greater extent and weeds utilized the energy which could turn into grain yield production (Table 3).

Table 2: Effect of treatments on energy studies (two year mean) under different treatments

Treatments	Input energy (MJ/ha)	Output energy (MJ/ha)	Energy use efficiency	Net energy returns (MJ/ha)	Energy intensity (MJ/Kg)
ZT x Sulfosulfuron 25g/ha	19045	149827	7.9	130782	4.2
ZT x Clodinofop60g/ha + MSM4g/ha (Readymix)	19081	168192	8.8	149111	3.5
ZT x Clodinofop60g/ha fb MSM4g/ha	19095	167545	8.8	148450	3.6
ZT x Pinoxaden 50g/ha fb MSM4g/ha	19089	168846	8.8	149757	3.5
ZT x Weed free	19162	170549	8.9	151387	3.4
ZT x Weedy	19021	112960	5.9	93939	6.2
RT x Sulfosulfuron 25g/ha	20430	140187	6.9	119757	4.8
RT x Clodinofop60g/ha + MSM4g/ha (Readymix)	20466	164322	8.0	143856	3.9
RT x Clodinofop60g/ha fb MSM4g/ha	20480	161535	7.9	141055	4.0
RT x Pinoxaden 50g/ha fb MSM4g/ha	20474	163057	8.0	142583	4.0
RT x Weed free	20618	167763	8.1	147145	3.8
RT x Weedy	20406	103200	5.1	82794	7.4
CT x Sulfosulfuron 25g/ha	21469	140158	6.5	118689	5.3
CT x Clodinofop60g/ha + MSM4g/ha (Readymix)	21505	156136	7.3	134631	4.4
CT x Clodinofop60g/ha fb MSM4g/ha	21519	153763	7.1	132244	4.5
CT x Pinoxaden 50g/ha fb MSM4g/ha	21513	158220	7.4	136707	4.3
CT x Weed free	21704	158656	7.3	136952	4.2
CT x Weedy	21445	95470	4.5	74025	8.6
*ZT= Zero tillage, RT= Reduced tillage, CT= Conventional tillage					

Table 3: Effect of treatments on grain and straw yields

Treatments	Grain yield q/ha		Straw yield q/ha	
	2012-13	**2013-14**	**2012-13**	**2013-14**
Tillage				
Zero tillage	48.56	49.32	67.98	67.01
Reduced tillage	46.25	46.80	65.59	64.98
Conventional tillage	44.01	43.65	64.35	62.54
SEm±	0.82	0.81	1.35	1.32
CD (5%)	3.31	3.27	NS	NS
Weed Management				
Sulfosulfuron 25g/ha	43.34	42.66	64.67	63.60
Clodinofop60g/ha + MSM4g/ha (Readymix)	51.03	52.14	69.62	69.70
Clodinofop60g/ha fb MSM4g/ha	50.52	51.02	68.81	69.33
Pinoxaden 50g/ha fb MSM4g/ha	51.48	52.18	70.14	69.87
Weed free	53.25	54.15	69.20	68.94
Weedy	28.00	27.40	53.41	47.64
SEm±	1.14	1.11	2.23	1.80
CD (5%)	3.32	3.23	6.49	5.24

Conclusion

Total energy input and output in zero tillage wheat (weed free) was 19162 and 170549 MJ/ha. The highest input energy was required in the conventional tillage systems and net energy return was lowest. The Energy use efficiency was also the highest in zero tillage systems whereas; the conventional tillage system is more energy intensive. Sowing of the zero tilled wheat with readymix application of clodinofop 60g/ha + MSM 4g/ha gives highest energy use efficiency and is least intensive after weed free treatment.

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