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Full Research Article

Effect of Weed-Control Measures on Yield, Weed Control, Economics, Energetics and Soil Microflora under Different Establishment Methods of Wheat (*Triticum aestivum* L.)

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Abstract

A field experiment was conducted during *rabi* season of 2013-2014 at Pantnagar, District, Udham Singh Nagar (Uttarakhand) to assess the effect of weed-control measures on grain yield, weed control efficiency (WCE), economics, energetic and soil microflora of wheat (*Triticum aestivum* L.) under different establishment methods. The highest grain (4688 kg ha^{-1}) and biological yield (12131 kg ha^{-1}) was obtained in the plots treated with clodinafop-propargyl @ 60 g ha^{-1}. Grain and biological yield loss under RTW, CTW and ZTW due to weeds was 75.9% and 30.8%, 22.3% and 11.5% and 18.3% and 14.3%, respectively. Ready mix of clodinafop-propargyl+MSM @ 64 g ha^{-1} in each establishment method of wheat recorded 100% weed control efficiency at 60, 90 DAS and at maturity. Highest B: C ratio (2.5) was achieved under clodinafop-propargyl @ 60 g ha^{-1} which was at par with ready mix of clodinafop-propargyl+MSM @ 64 g ha^{-1}. Maximum energy input (15717 MJ ha^{-1}) was recorded under CTW with two hand weedings and the lowest energy input (15113 MJ ha^{-1}) was recorded under RTW in weedy plot which was closely followed by weedy plots of ZTW. Energy output (171483 MJ ha^{-1}), net energy return (156354 MJ ha^{-1}) and energy use efficiency (11.3) was maximum in case of RTW plots where ready mix of clodinafop-propargyl+MSM @ 64 gha^{-1} was applied. Energy intensity (3.0) was lowest under RTW with clodinafop-propargyl @ 60 g ha^{-1}. The lowest population of bacteria (6.87 log cfu) and actinomycetes (5.46 log cfu) was recorded under ready mix of clodinafop-propargyl+MSM @ 64 g ha^{-1}.

1. Introduction

Wheat (*Triticum aestivum* L.) is the world's most widely cultivated food crop and in India it is second important staple food, rice being the first. As a result of ever increasing population, India will need 109 mt of wheat during the year 2020 AD, which can be achieved by increasing its productivity 4.29 t ha^{-1} and annual growth rate of 4.1% (Mishra, 2007). The exhaustive rice wheat cropping system (RWCS) practiced with conventional tillage (CT) has resulted in lower marginal returns (Ladha et al., 2000), delay in wheat sowing and reduces wheat yield (Gangwar et al., 2005). Whereas zero tillage reduces production costs, saves water, increases soil organic matter, prevents soil erosion, mitigates greenhouse gases from the soil, improves air quality, protects wildlife habitat and biodiversity, improves production and ensures environmental safety (Gupta et al., 2002; Khan et al., 2004). Weeds cause yield reduction to the tune of 15 to 50% or sometime more depending upon the weed density and weed flora (Jat et al., 2003). Wheat fields in Northern India are badly infested with wide range of grassy and broad leaf weeds in general and *Phalaris minor* Retz. in particular. Weeds can be effectively controlled with the use of selective herbicides. As a result of this, different herbicides like clodinafop-propargyl and metsulfuron methyl have been tested. The actions of these herbicides on weeds have been tested under conventional method of wheat sowing but new techniques of establishment of wheat revealed different types of weed flora with different density of weeds and their management practices are also different to the conventional system.

In recent years, the major emphasis in the rice-wheat system has been on alternative resource conservation technologies for both rice and wheat to reduce the cost of cultivation and energy consumption, to sustain productivity, and to increase the profit margin of farmers (Singh et al., 2006). Adoption of proper establishment methods and weed management practices can raise wheat productivity substantially and can make it cost and energy effective. Zero till and roto till seed drill is an alternative for wheat establishment which saves the time and energy whereas considerable amount of these valuable resources are spent on preparing the land for wheat cultivation (Kumar et al., 2013). Soil micro flora is also disturbed by changing the establishment methods and replacing present herbicides with newer ones like clodinafop-propargyl, metsulfuron methyl, etc., Hence, attempt has been made to assess the effect of different establishment methods and weed control methods on soil micro flora and energy consumption.

2. Materials and Methods

A field experiment was conducted during *rabi* season of 2013-2014 in the D-2 block of Norman E. Borlaug, Crop Research Centre (CRC) of G.B Pant University of Agriculture and Technology, Pantnagar, District, Udham Singh Nagar (Uttarakhand). The soil was silty clay loam, with pH 7.2, medium in organic carbon (0.70%) and available nitrogen (217.5 kg ha^{-1}) and medium in available phosphorus (21.9 kg ha^{-1}) and available potash (190.3 kg ha^{-1}). Three establishment methods viz., (ZTW) zero tillage with rice straw 3 t ha^{-1} (50% of general straw yield), (RTW) roto till seed drill and (CTW) conventional tillage in the main plots and four weed management practices viz., weedy check, two hand weedings (30 and 60 days after sowing), clodinafop-propargyl @ 60 g ha^{-1} and ready mix of clodinafop-propargyl 15%+metsulfuron methyl 1% @ 64 g ha^{-1} in the subplots were tested in split plot design with 3 replications. The experimental wheat crop was fertilized uniformly with 150: 60: 40 kg ha^{-1} of N, P and K, respectively. The variety PBW 502 was sown with a seed rate of 100 kg ha^{-1} on 14 November, 2013 and harvested on 17 April, 2014. In case of zero tillage, zero till ferti seed drill was used for sowing. Under roto tillage, the sowing was done with the roto till seed drill and in conventional system, general wheat seed drill was used for sowing. Herbicides were sprayed in the aqueous medium using 500 litres of water ha^{-1} with the help of Maruti foot sprayer fitted with a flat fan nozzle. Weed control efficiency was calculated by using the following formula (Walia, 2012):

$$\text{WCE (\%)} = \frac{\text{WDC - WDT}}{\text{WDC}} \times 100$$

Where, WDC=Weed dry weight in control plot (g m^{-2})
And WDT=Weed dry weight in treated plot (g m^{-2}).
Benefit: Cost ratio was calculated to assess the economics of wheat crop due to various treatments**.** To calculate the input energy, all inputs in the form of labour, seed, water, chemical fertilizers and herbicides used were taken into consideration using the energy conversion factors. The energy requirement for the different field operations was calculated by using the energy conversion factors as given in Table 1. Energy equivalents for all the inputs were summed up to provide an estimate for total energy input. The farm produce (grain yield+straw yield) was also converted into energy in terms of energy output (MJ). Output energy from the produce (grain and straw) was calculated by multiplying the amount of production and its corresponding equivalents. Energy use efficiency, net energy gain and energy intensity for wheat production were calculated using the following formulae (Canakci et al., 2005).

Table 1: Energy equivalents of inputs and outputs used in the study

Sl. no.	Particulars	Unit	Energy equivalent (MJ $unit^{-1}$)
Input			
1.	Human labour	Hr	1.96
2.	Machinery	Hr	62.7
3.	Diesel fuel	L	56.31
4.	Chemical fertilizers		
	• Nitrogen (N)		66.14
	• Phosphate (P_2O_5)		12.44
	• Potassium (K_2O)	Kg	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

Energy use efficiency (EUE)

$$\text{EUE} = \frac{\text{Output energy}}{\text{Input energy (MJ ha}^{-1})}$$

Net energy returns (NER)

Net energy =Energy output (MJ ha^{-1})–Energy input (MJ ha^{-1})

Energy intensity (EI)

$$\text{EI(MJ kg}^{-1} = \frac{\text{Energy intput (MJ ha}^{-1})}{\text{Grain yield (kg ha}^{-1})}$$

Total bacterial, fungal and actinomycetes populations were enumerated using serial dilution technique and pour plate method. After appropriate incubation period, the colonies of microorganisms appearing on plates were counted following standard method (Pramer and Schmidt, 1964). Nutrient agar medium (Johnson and Curl, 1972) was used for total bacterial count, Martin's Dextrose Rose agar medium and Starch ammonium agar medium were used for fungi and actinomycetes, respectively.

3. Results and Discussion

3.1. Total weeds dry weight

The dry matter accumulation (Table 2) was highest under RTW which was at par with CTW and significantly higher than ZTW at 30, 90 DAS and at maturity except at 60 DAS, where CTW and ZTW were at par. The higher dry matter accumulation of total weeds under RTW was might be due to higher population of total weeds under this particular treatment. Sharma, et al. (2004) also reported the similar findings. The dry matter accumulation of total weeds increased with increase in crop age under weedy situation. Clodinafop-propargyl @ 60 g ha^{-1} alone recorded significantly less weed dry matter production over two hand weedings at 30, 60, and 90 DAS except at maturity. Bhullar and Walia (2004) also reported that application of clodinafop 60 g ha^{-1} resulted in 80.3% reduction in the weed dry matter accumulation of the weeds. Due to delay in hand weeding at 30 and 60 DAS, the population of weeds was higher and as a result dry matter was also higher. At all the stages (30, 60, 90 DAS and maturity) ready mix of clodinafop-propargyl+MSM @ 64 g ha^{-1} recorded the lowest weed dry matter accumulation as it effectively controls the grassy and BLWs population to cent percent.

3.2. Weed control efficiency

Ready mix of clodinafop-propargyl+MSM @ 64 g ha^{-1} in each establishment method of wheat recorded 100% weed control efficiency (Table 3) at 60, 90 DAS and at maturity stage, which highlights the effectiveness of this combination of herbicides against grassy as well as BLWs. Under ZTW, alone application of clodinafop-propargyl @ 60 g ha^{-1} recorded 94.7% weed control efficiency at 60 DAS whereas, at 90 DAS and maturity, recorded 29.1 and 36.9% weed control efficiency, respectively.

Table 2: Total weeds dry matter (g m^{-2}) at various stages of the crop growth as influenced by different establishment methods and weed control measures in wheat

Treatments	Total weed dry matter (g m^{-2}) accumulation			
	30 DAS	60 DAS	90 DAS	At maturity
A. Establishment method				
Zero tilled wheat	0.00 (0.00)	2.33 (26.5)	2.07 (14.9)	2.12 (16.0)
Conventional tilled wheat	1.31 (2.9)	2.41 (31.3)	2.62 (50.7)	2.50 (51.7)
Roto till drilled wheat	1.44 (3.2)	2.81 (44.1)	2.65 (76.8)	2.55 (84.7)
SEm±	0.03	0.07	0.08	0.05
CD (p=0.05)	0.13	0.28	0.32	0.20
B. Weed management practices				
Weedy	0.86 (1.77)	4.45 (87.4)	4.77 (164.4)	4.85 (179.3)
Two hand weeding	1.07 (2.72)	3.66 (41.3)	2.69 (15.2)	2.43 (12.0)
Clodinafop-propargyl @ 60g ha^{-1}	0.92 (2.03)	1.96 (7.2)	2.34 (10.4)	2.38 (11.9)
Ready mix of Clodinafop-propargyl+ MSM @ 64 g ha^{-1}	0.82 (1.68)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
SEm±	0.02	0.10	0.05	0.06
CD (p=0.05)	0.07	0.29	0.14	0.18

Original values are given in parantheses

Treatments	Weed control efficiency (%)		
	60 DAS	90 DAS	At maturity
ZTW×Weedy	0.0	0.0	0.0
ZTW×Two hand weedings	46.8	84.8	85.4
ZTW×Clodinafop-propargyl @ 60 g ha^{-1}	94.7	29.1	36.9
ZTW×Clodinafop-propargyl+MSM @ 64 g ha^{-1}	100	100	100
CTW×Weedy	0.0	0.0	0.0
CTW×Two hand weedings	63.8	90.8	89.6
CTW×Clodinafop-propargyl @ 60 g ha^{-1}	93.3	93.8	95.8
CTW×Clodinafop-propargyl+MSM @ 64 g ha^{-1}	100	100	100
RTW×Weedy	0.00	0.0	0.0
RTW×Two hand weedings	49.5	96.5	96.3
RTW×Clodinafop-propargyl @ 60 g ha^{-1}	88.4	95.9	98.3
RTW×Clodinafop-propargyl+MSM @ 64 g ha^{-1}	100	100	100

It was due the effectiveness of clodinafop-propargyl against grassy weeds only and broad leaf weeds emerged latter part of crop growth stage and also they were not controlled by this herbicide. In case of CTW and RTW, with clodinafop-propargyl @ 60 g ha^{-1}, weed control efficiency was 93.4 and 88.4, 93.8 and 95.9, 95.8 and 98.3% at 60, 90 DAS and at maturity, respectively. It was because of dominance of *Phalaris minor* in these establishment methods which was effectively controlled by clodinafop-propargyl application. Chauhan et al. (2000) also reported the similar findings.

3.3. *Yield contributing characters*

3.3.1. *Number of spikes m^{-2}*

Establishment methods of wheat did not affect spikes m^{-2} (Table 4) significantly. Spikes m^{-2} were highest under CTW followed by ZTW and lowest in RTW, although, the difference was not significant. All the weed management practices produced significantly higher number of spike m^{-2} over weedy plot. Ready mix of clodinafop-propargyl+MSM @ 64 g ha^{-1} recorded highest number of spike m^{-2} which was at par with two hand weedings and significantly higher over clodinafop-propargyl @ 60 g ha^{-1} (Singh., 2013) also reported the similar findings. The highest number of spikes m^{-2} under ready mix of clodinafo-propargyl+MSM @ 64 g ha^{-1} might be due to effective control of grassy as well as BLWs which reduced the crop weed competition and enhanced the number of effective tillers and spikes as well. Chhokar and Malik (2002); Bharat et al. (2010) also concluded that metsulfuron and clodinafop were effective against broad-leaved and grassy weeds, respectively.

3.3.2. *Spike length*

Differences in spike length (Table 4) due to wheat establishment methods as well as weed management practices were found non-significant. However, longest spike length has been recorded in case of ZTW and shortest in RTW. Among different weed management practices, spike length was longest in case of clodinafop-propargyl @ 60 g ha^{-1} whereas, it was shortest under weedy check.

3.3.3. *Number of grains spike^{-1}*

Number of grains spike^{-1} (Table 4) exhibited non-significant variation owing to wheat establishment methods, whereas; weed management practices influenced number of grains spike^{-1} significantly. Numerically, CTW recorded maximum number of grains spike^{-1} while minimum was found in case of RTW. All the weed control measures produced significantly higher number of grains spike^{-1} over weedy plot. Ready mix of clodinafop-propargyl+MSM @ 64 g ha^{-1} among the various weed control measures produced maximum number of grains spike^{-1} which was at par with clodinafop-propargyl @ 60 g ha^{-1} and significantly higher than two hand weedings. Singh (2013) also reported the similar findings. It might be due to better source to sink relationship which resulted due to less crop weed competition as ready mix of clodinafop-propargyl+MSM @ 64 g ha^{-1} controlled the total weed population.

Table 4: Yield attributing characters of crop as affected by establishment methods and weed control measures

Treatments	No. of spikes m^{-2}	Spike length (cm)	Number of grains spike^{-1}	1000–grain weight (g)
A. Establishment method				
Zero tilled wheat	341	14.35	40	41.41
Conventional tilled wheat	389	13.61	42	40.27
Roto till drilled wheat	313	13.51	39	40.92
SEm±	18.93	0.26	0.52	0.69
CD (*p*=0.05)	NS	NS	NS	NS
B. Weed management practices				
Weedy	232	13.36	35	38.39
Two hand weeding	380	14.07	39	41.32
Clodinafop-propargyl @ 60g ha^{-1}	372	14.19	43	40.94
Ready mix of Clodinafop-propargyl+MSM @ 64 g ha^{-1}	405	13.68	45	42.83
SEm±	10.49	0.25	1.51	0.70
CD (*p*=0.05)	31	NS	5.0	2.08

3.3.4. *1000-grain weight*

Variation in thousand grain weight (Table 4) attributed to wheat establishment methods was found non-significant. All weed management practices provided significantly better condition than unweeded control as to accumulate the dry matter in grains. The data further indicated that crop given ready mix of clodinafop-propargyl+MSM @ 64 g ha^{-1} had highest test weight of wheat which was at par with two hand weedings and clodinafop-propargyl @ 60 g ha^{-1}. This finding confirms the results of Singh (2013).

3.4. *Wheat grain, biological yield and B:C ratio*

All the weed control measures applied plots produced significantly higher grain and biological yield (Table 5) than weedy check. The highest grain yield (4688 kg ha^{-1}) was obtained in the plots treated with clodinafop-propargyl @ 60 g ha^{-1} at par with ready mix of clodinafop-propargyl+MSM @ 64 g ha^{-1} (4561 kg ha^{-1}) and two hand weedings (4515 kg ha^{-1}). The grain yield under clodinafop-propargyl @ 60 g ha^{-1}, ready mix of clodinafop-propargyl+MSM @ 64 g ha^{-1} and two hand weedings was 39%, 37% and 36% higher than weedy check, respectively. Reasons attributed to higher yield were higher dry matter production by crop, higher weed control efficiency which ranged up to 98.3% and 100% by application of clodinafop-propargyl @ 60 g ha^{-1} and ready mix of clodinafop-propargyl+MSM @ 64 g ha^{-1}, respectively and higher number of spikes per metre square. Tiwari and Vaishya (2004) and Brar et al. (2003) also reported the same findings and concluded that clodinafop-propargyl @ 60 g ha^{-1} recorded maximum grain yield. The highest biological yield (12131 kg ha^{-1}) was obtained with crop given ready mix of clodinafop-propargyl+MSM @ 64 g ha^{-1} which was at par with clodinafop-propargyl @ 60 g ha^{-1} and two hand weedings. This indicates that effective weed control reduces competition between crops and weeds which results in higher yield. Similar trends were obsereved by Pandey et al. (2006). Highest B: C ratio (Table 5) was recorded under ZTW followed by RTW. The lowest B: C ratio was recorded under CTW. Higher B: C ratio in ZTW and RTW is attributed to the lower cost of cultivation, although the grain yield was higher under CTW but cost of cultivation was much higher than that of ZTW and RTW. Gangwar et al., 2005 also reported the same finding and concluded that B: C ratio was higher in case of zero tillage rather than CTW. Weed management practices also influenced the B: C ratio significantly. Highest B: C ratio was achieved under clodinafop-propargyl @ 60 g ha^{-1} which was at par with ready mix of clodinafop-propargyl+ MSM @ 64 g ha^{-1} and significantly higher over two hand weedings. Lower B: C ratio under two hand weedings was due to higher cost of hand weeding, whereas, chemicals were cheaper and labour requirement was also less. Singh et al. (2004) confirms the same findings.

Table 5: Grain yield, biological yield and B: C ratio as influenced by different establishment methods and weed control measures in wheat

Treatments	Grain yield (kg ha^{-1})	Biological yield (kg ha-1)	B: C ratio
A. Establishment method			
Zero tilled wheat	4106	11473	2.3
Conventional tilled wheat	4442	11586	2.0
Roto till drilled wheat	3914	11460	2.1
SEm±	133	163	0.08
CD (*p*=0.05)	NS	NS	NS
B. Weed management practices			
Weedy	2852	10004	1.5
Two hand weeding	4515	11821	2.1
Clodinafop-propargyl @ 60g ha^{-1}	4688	12070	2.5
Ready mix of Clodinafop-propargyl+MSM @ 64 g ha^{-1}	4561	12131	2.4
SEm±	132	190	0.07
CD (*p*=0.05)	391	564	0.21

3.5. *Energy studies*

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 (Table 6) was recorded maximum under CTW with two hand weedings and the lowest energy input was recorded under RTW with weedy which was closely followed by ZTW with weedy. Higher energy consumption in CTW with two hand weedings was because of more energy incurred inland preparation and sowing. Sharma et al., 2002 also observed the similar findings. Energy output and net energy return (Table 6) was found to be the maximum in the RTW plots where clodinafop-propargyl+MSM @ 64 g ha^{-1} was applied followed by RTW with clodinafop-propargyl at 60 g ha^{-1} due to higher grain and straw yield in these treatments. The lowest energy output was recorded under RTW when weeds were not controlled as grain and straw yield was negatively affected by heavy weed infestation particularly *Phalaris minor.*

Energy use efficiency (Table 6) was the maximum in case of RTW plots where clodinafop-propargyl+MSM @ 64 g ha^{-1} was applied followed by RTW with clodinafop-propargyl @ 60 g ha^{-1}. This is resulted from higher energy output and lower energy input in these treatment combinations. Energy use efficiency in general was low in case of CTW. Kumar et al., 2013 reported the similar finding. Energy intensity (Table 6) was lowest under RTW with clodinafop–propargyl @ 60 g ha^{-1} followed by clodinafop-propargyl+MSM @ 64 g ha^{-1} under the same establishment method. 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.

3.6. *Soil micro flora*

Population of fungi, bacteria and actinomycetes (Table 7) was not influenced significantly with respect to wheat establishment methods at 60 DAS but numerically, ZTW recorded maximum

Treatments	Input energy (MJ ha^{-1})	Output energy (MJ ha^{-1})	Energy use efficiency	Net energy returns (MJ ha^{-1})	Energy intensity (MJ Kg^{-1})
ZTW×Weedy	15115	137610	9.1	122495	4.1
ZTW×Two hand weedings	15197	154160	10.1	138963	3.7
ZTW×Clodinafop-propargyl @ 60 g ha^{-1}	15130	160969	10.6	145839	3.4
ZTW×Clodinafop-propargyl+ MSM @ 64 g ha^{-1}	15131	157060	10.4	141929	3.6
CTW×Weedy	15482	142244	9.2	126762	4.2
CTW×Two hand weedings	15717	162014	10.3	146297	3.3
CTW×Clodinafop-propargyl @ 60 g ha^{-1}	15497	157666	10.2	142169	3.4
CTW×Clodinafop-propargyl+ MSM @ 64 g ha^{-1}	15498	156478	10.1	140980	3.3
RTW×Weedy	15113	114110	7.6	98997	12.6
RTW×Two hand weedings	15371	156920	10.2	141549	3.3
RTW×Clodinafop-propargyl @ 60 g ha^{-1}	15128	164918	10.9	149790	3.0
RTW×Clodinafop-propargyl+MSM @ 64 g ha^{-1}	15129	171483	11.3	156354	3.2

Table 7: Soil microbial population at 60 DAS as affected by various establishment methods and weed control measures

Treatments	Microbial population at 60 DAS		
	Fungi (log cfu)	Bacteria (log cfu)	Actinomycetes (log cfu)
A. Establishment method			
Zero tilled wheat	7.99	7.03	5.64
Conventional tilled wheat	7.92	6.97	5.60
Roto till drilled wheat	7.95	7.00	5.62
SEm±	0.03	0.04	0.02
CD (p=0.05)	NS	NS	NS
B. Weed management practices			
Weedy	8.10	7.14	5.78
Two hand weeding	8.03	7.07	5.73
Clodinafop-propargyl @ 60 g ha^{-1}	7.87	6.93	5.51
Ready mix of Clodinafop-propargyl+MSM @ 64 g ha^{-1}	7.81	6.87	5.46
SEm±	0.09	0.05	0.06
CD (p=0.05)	NS	0.15	0.16

population of fungi, bacteria and actinomycetes followed by RTW and CTW.

It might be attributed to the disturbance or tillage intensity to the soil. ZTW was the least disturbed soil followed by RTW and CTW. Reduced tillage has been shown to enhance soil microbial diversity (Hassink et al., 1991; Wander et al., 1995). Under weed management practices, weedy plots recorded maximum population of fungi, bacteria and actinomycetes at 60 DAS but population of fungi was not significantly influenced. The lowest population of bacteria and actinomycetes was recorded under ready mix of clodinafop-propargyl+MSM @ 64 g ha^{-1} which was at par with clodinafop-propargyl @ 60 g ha^{-1}. It might be due to application of clodinafop-propargyl and MSM may negatively influence the microbial population. He (2006) also reported that the common bacteria group was distinctly inhibited by metsulfuron-methyl at a concentration of 2 mg kg^{-1}. Similarly Saini et al. (2009) also reported that at early stages after the application of clodinafop, bacterial population was significantly less in plots sprayed with clodinafop as a component of herbicide rotations than in plots sprayed with clodinafop continuously and weedy control.

4. Conclusion

Wheat establishment method roto till drilled wheat along with clodinafop-propargyl @ 60 g ha^{-1} achieved significant control of weeds, grain yield, comparatively less energy intensity and highest B: C ratio was obtained in this treatment combination.

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