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Effect of weed management practices and seed rates on economics and energetics on direct seeded rice production system

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Abstract
An experiment was conducted, for two consecutive years to evaluate the effect of weed management practices and seed rates on economics and energetics on direct seeded rice production system. Experiment was conducted during *kharif* 2013 and 2014 in *Inceptisols*. Rice variety MTU 1010 was taken as test crop. The experiment was laid out in strip plot design in vertical strip six weed management practices comprising two hand weeding, application of pre and post emergence herbicide *i.e.* bispyribac-Na, pretilachlor + bensulfuron, azimsulfuron and weedy check was allotted and in horizonatal strips three seed rates ranging from *viz.*, 80, 60 and 40, kg ha^{-1} was arranged. The mean of grain yield over two seasons revealed that significantly higher grain yield was recorded in two hand weeding and it was at par with the chemical control method application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Significantly superior net return and B: C was found with application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS which was at par with two hand weeding. The relation between agriculture and energy is very close, agricultural sector itself is an energy user and energy supplier in the form of bio-energy. The energy input output, energy use efficiency and energy productivity was significantly higher with application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS over other treatments.

Keywords: Direct seeded rice, seed rate, weed management, economics, energy use efficiency, energy productivity

Introduction
Rice (*Oryza sativa* L.) is the most important staple food crop of millions of mankind from dawn of civilization (Chakravarti *et al.*, 2012) [2]. Chhattisgarh state is popularly known as "Rice bowl" because of maximum area covered during *kharif* under rice contributing major share in national rice production. Direct seeding of rice has evolved as a potential alternative to the current detrimental practice of puddling and nursery transplanting. The associated benefits include higher water productivity, less labor and energy inputs, less methane emissions, elimination of time and edaphic conflicts in the rice–wheat cropping system, and early crop maturity. Hand weeding is the most common and effective method of weed control in rice, but it is being difficult and uneconomical day-by-day due to high wages and non-availability of labours at peak period of farm operation (Singh *et al.* 1999) [14]. In Chhattisgarh state, farmers generally control weeds manually. The physical methods are costly and labour intensive and advantage of manual weeding could only be achieved when it is performed timely.

The productivity of rice per unit area in Chhattisgarh is poor, despite of suitable environmental conditions. One of major problem in rice cultivation for low productivity is weed infestation. Nowadays, herbicides are gaining popularity because of their selectiveness, effectiveness and convenience to use. Herbicides have resulted in easier crop husbandry and have lowered down the cost of cultivation. Herbicide is the most effective and economic means of weed control, but inappropriate or wrong application may not only increase production cost and yield penalty but also may cause development of herbicide resistant weeds and environmental hazard (Karim *et al.*, 2004) [7]. Seed rate is an important agronomic parameter, the seed rate per unit area depends upon germination of seed, size of the seed, growing habit of the crop, time of sowing, type of farming, variety *etc*. Too high or too low seed rate affect the plant population and yield of crop. Higher seed rate will influence higher plant population per unit area. It result in heavy competition within the crop plants and suppresses the crop growth. Whereas lower seed rate will result lower plant population thereby lowers the yield per unit area.

The relation between agriculture and energy is very close. Agricultural sector itself is an energy user and energy supplier in the form of bio-energy (Alam *et al*., 2005) [1]. Efficient use of these energies helps to achieve increased production and productivity and contributes to the profitability and competitiveness of agriculture sustainability in rural living (Singh *et al*., 2002) [15]. 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) [8].

The aims of this study were to determine economics and to investigate the economic return and efficiency of energy consumption in both the situation if harvesting is done by the manually or through harvester.

Materials and Methods

An experiment was conducted during *kharif* 2013 and 2014 at Instructional cum research farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The soil of the experimental field was *Inceptisols* known as *matasi*. The soil was neutral in reaction, low in organic carbon, low in nitrogen, medium in phosohorus and high in potash contents. Climate was suitable during cropping period in both the years for rice rainfall received during the cropping season of *kharif*2013 and 2014 was 1574 mm and 1029 mm, respectively. The mean maximum temperature ranged from 25.7 ^{0}C to 21.4 ^{0}C and 27^{0}C to 17.6 ^{0}C during the investigation. Sun shine hours ranged from 8.6 to 0.7 and 8.3 to 0.5 per day during 2013 and 2014.Relative humidity throughout the crop season varied between 80 to 95 per cent at morning and 44 to 80 per cent in evening hours in both the years.

The experiment was laid out in strip plot design with three replication. The vertical strip comprised of six weed management practices *i.e.* (W_1) Two hand weeding, (W_2) Bispyribac-Na @ 25 g ha^{-1} at 20DAS, (W_3) PE Oxadiargyl 70 g ha^{-1}*fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS, (W_4) PE Pretilachlor + Bensulfuron 660 g ha^{-1}*fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS, (W_5) Azimsulfuron 35 g ha^{-1}*fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS, (W_6) weedy check in vertical strips; and three seed rates ranging from *viz.*, (S_1)80, (S_2)60 and (S_3)40, kg ha^{-1} in horizonatal strips was allocated. Rice variety MTU 1010 was taken as test crop. Sowing was done after the first monsoon under wet condition with the fertilizer application of 100, 60 and 40 kg N, P_2O_5 and K_2O ha^{-1}. The recommended package and practices except treatment was followed and treatments were imposed as per the plan. The herbicides were applied using knapsack sprayer fitted with flat fan nozzle by mixing 500 litres of water per ha. During the investigation harvesting was done manually. But now-a-days farmers are harvesting their crop through harvester to save time, minimize the cost which may be the solution of labour dependency in large area of Chhattisgarh. Therefore, to understand the economics and energetics of manual harvesting and harvesting through harvester primary data are used to calculate the economics and energetics of rice production system through harvester, other operation are same in both the situation.

Cost of cultivation of various treatments were estimated on the basis of approved market rates for inputs by taking into account cost of seed, fertilizer, herbicides, pesticides, hiring charges of human labour and machines for different field operations. Gross return (Rs. ha^{-1}) was obtained by converting the harvested produce into monetary terms at the prevailing market rate during the course of studies for every treatment. Net return was obtained by deducting cost of cultivation from the gross return. The benefit: cost ratio was calculated by dividing net return with cost of cultivation. To calculate the cost of cultivation labour rate of MNREGA during 2013 & 2014 and C.G. Government procurement rate of produce are considered to calculate the economics.

Energy inputs were calculated and estimated in Mega Joule (MJ) ha^{-1} with reference to the standard values prescribed by Mittal *et al.* (1985) [10]. These inputs were taken to each treatment of rice crop. The standard energy coefficient for seed and straw of rice was multiplied with their respective yields and summed up to obtain total energy output.

The energy requirements for direct line seeded rice cultivation under different treatments method using labour, seed, fertilizer, herbicides *etc*. was estimated on the basis of standard energy coefficients. Output energy was estimated with seed and straw yields with standard energy coefficients. The standard energy coefficient for seed and straw of rice was multiplied with their respective yields and summed to obtain energy use efficiency, energy productivity. Energy use efficiency and Energy productivity were calculated as per the following formulae.

$$\text{Energy use efficiency (q MJX } 10^3) = \frac{\text{Total produce (q)}}{\text{Energy input (MJ X}10^3)}$$

$$\text{Energy productivity (kg MJ ha}^{-1}) = \frac{\text{Mean Grain Yield (kg ha}^{-1})}{\text{Total energy input, MJ}}$$

$$\text{Energy Output –Input Ratio} = \frac{\text{Energy Output (MJha}^{-1})}{\text{Input Ratio (MJha}^{-1})}$$

Data obtained from the experiment were statistically analyzed using F-test (Gomez and Gomez, 1984) [3]. LSD values at = 0.05 were used to determine the significance of difference between the treatment means.

Results and Discussion

Seed yield

The data with respect to seed yield are presented in table 1. Seed yield was significantly influenced by different weed management practices. Among different weed management practices, two hand weeding at 20 and 40 DAS method was significantly superior over weedy check. However, it was at par with the chemical control method application of pre - emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Hand weeding twice produced 258 percent more grain yield as compared to the weedy check. However, difference between hand weeding and best chemical control method was only two percent, shows that chemical control method with proper dose and time may be the alternative of manual weeding in direct seeded rice line sown rice. Nagappa and Biradar (2002) [12], Walia *et al.* (2009) [16], Hussain *et al.* (2009) [5] and Kiran *et al.* (2010) [9] was also reported similar result. Seed rates ranging from 40 to 80 kg ha^{-1}was found non significant. Similar result was also reported by Ravi Gopal (2008) [13], Yadav *et al.* (2007) [17] and Gill *et al.* (2007) [4]. Straw yield was recorded maximum in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS which was at par to all the weed managment treatments. Minimum straw yield was recorded in weedy check due to more dry matter of weed and its density in the plot, high crop-weed competition which does not allow

crop to growth with their genetic potential. Similar result in harvest index was recorded during experimentation.

Economics

The data with respect to cost of cultivation, gross return, net return and benefit cost are presented in Table 3. Cost of cultivation on the basis of two year mean ranging from Rs 30047 to 22122. Gross income of direct line seeded rice was maximum with hand weeding twice (Rs 86690) and was at par with application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (Rs 85151) and azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS (Rs 83238). However, minimum gross return was recorded under weedy check.

Significantly superior net return was found with application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (Rs 56880) and it was at par with two hand weeding (Rs 56643) and azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS (Rs 53595) in case of manual harvesting. However, in case of harvesting through harvester significantly higher net return was recorded under hand weeding (Rs 67992) which was at par with application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (Rs 67785). Difference between manual harvesting and harvesting through harvester was nearly Rs 10000 which is significant difference and supports the *"machine to machine rice production system"*. Among the seed rates cost of cultivation, gross income and net income does not show any critical difference in both the year in both the harvesting system.

B: C ratio of harvesting through harvester was higher as compared to the manual harvesting it was significantly higher in application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (2.6) and at par with two hand weeding twice. High monetary income per rupee invested can be achievd through harvesting with harvester. The lowest B: C ratio (0.15) was found in un-weeded control treatment. Among the seed rate, highest B: C ratio was found in 40 kg seed rate ha^{-1} followed by 60 Kg and 120 Kg ha^{-1} seed rate. Similar result was also reported by Hussain *et al*. (2008) [6] and Kiran *et al*. (2010) [9].

Energetics

The relation between agriculture and energy is very close. Agricultural sector itself is an energy user and energy supplier in the form of bio-energy (Alam *et al*., 2005) [1]. Agriculture is both a producer and consumer of energy. Efficient use of these energies helps to achieve increased production and productivity and contributes to the profitability and competitiveness of agriculture sustainability in rural living (Singh *et al*., 2002) [15]. Input energy was highest (12.1 MJ X 10^3) in two hand weeding method followed by chemical treatments (ranging from 11.5 to 11.6 MJ X 10^3). However, the minimum energy required in weedy check method due to less labour required for harvesting and processing the produce(11.1 MJ X 10^3). In case of harvester input energy was high in combine harvester due to the use of heavy machine, high consumption of diesel as compared to manual harvesting system (ranging from 12.8 to 12.2 MJ X 10^3). Maximum output energy was recorded under two hand weeding and was at par with pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS, and azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Significantly lowest output energy was recorded under the weedy check. This situation clearly indicates that the weeds are the major factor in production system. Energy was consumed by the weed for their growth and development in place of rice plant. During the investigation seed rate does not influence the output energy.

The energy input output analysis is usually made to measure the energy efficiency. This analysis will determine how efficient the energy is used. Significantly higher energy output input ratio was found with application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and was at par with hand weeing twice and application of azimsulfuron 35 g ha^{-1} fb bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Output input energy was almost equal in chemical control and hand weeding which supports the use of herbicides in rice production system. Efficient use of these energies helps to achieve increased production and productivity and contributes to the profitability and competitiveness of agriculture sustainability in rural living (Singh *et al*., 2002) [15].

Significantly, maximum energy use efficiency was recorded under with application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and was at par with two hand weeding and azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. However, it was found minimum under weedy check. Difference between hand weeding and chemical control in respect to energy use efficincy was similar and produced nearly equal biological yield (q MJ ha^{-1}) and supports chemical control may be the alternative of hand weeding in direct line seeded rice production system. Energy productivity is an important indicator for more efficient use of energy although higher energy productivity does not mean in general, more economic feasibility (Mohammadi *et al*., 2010) [11]. Energy productivity (kg MJ ha^{-1}) was recorded maximum in pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS treatment which was at par with hand weeding.

Table 1: Effect of different weed management practices and seed rate on yield and energetics of direct line seeded rice (mean of two year 2013 and 2014)

Treatment	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)	Total input energy ha^{-1} (MJ $X10^3$) 2013 & 2014	Total input energy ha^{-1} (MJ $X10^3$) 2013 & 2014	Total output energy ha^{-1} (MJ $X10^3$)
				Manual	Harvester	
Weed management						
W_1:- Two hand weeding	52.61	65.84	44.53	12.1	12.8	159.6
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	47.45	59.78	43.84	11.5	12.2	144.7
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	51.62	65.94	44.09	11.5	12.2	158.3
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	49.38	63.13	43.93	11.6	12.3	151.5
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1}	50.52	63.38	44.34	11.5	12.2	153.5

at 15 and 35 DAS						
W_6:- Weedy check	14.69	27.81	34.10	11.1	12.2	56.4
SEm±	.73	1.74	0.77			
CD (P = 0.05)	2.31	5.48	2.43			
Seed rate (kg ha^{-1})						
S_1:- 80	43.84	56.81	42.26	11.8	12.6	131.0
S_2:- 60	43.64	57.85	41.86	11.5	12.3	132.2
S_3:- 40	45.92	58.28	43.30	11.3	12.0	135.8
SEm±	0.49	.75	0.32			1.4
CD (P = 0.05)	NS	NS	NS			NS
Interaction (WM X SR)	NS	NS	NS			NS

Table 2: Effect of different weed management practices and seed rate on energy output – input ratio, energy use efficiency and energy productivity of direct line seeded rice (mean of two year 2013 and 2014)

Treatment	Energy Output – input ratio		Energy Use Efficiency (q MJ X10^3)		Energy Productivity (kg MJ ha^{-1})	
	Manual	Harvester	Manual	Harvester	Manual	Harvester
Weed management						
W_1:- Two hand weeding	13.2	12.5	9.8	9.5	0.44	.41
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	12.6	11.9	9.4	9.0	0.41	.39
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	13.8	12.9	10.2	9.8	0.45	.42
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	13.1	12.3	9.7	9.4	0.43	.40
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	13.3	12.6	9.9	9.5	0.44	.41
W_6:- Weedy check	5.1	4.6	3.8	4.0	0.13	.12
SEm±	0.2	0.2	0.17	0.16	0.01	0.01
CD (P = 0.05)	0.7	0.6	0.53	0.50	0.02	0.02
Seed rate (kg ha^{-1})						
S_1:- 80	11.4	10.7	8.4	8.2	0.37	.35
S_2:- 60	11.8	11.1	8.7	8.5	0.38	.36
S_3:- 40	12.4	11.7	9.2	8.9	0.41	.39
SEm±	0.1	0.1	0.09	0.09	0.1	0.01
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS

Table 3: Effect of different weed management practices and seed rate on economics of direct line seeded rice (mean of two year 2013 and 2014)

Treatment	Total Cost (Rs ha^{-1})		Gross Income (Rs ha^{-1})	Net Income through Manual (Rs ha^{-1})		B:C	
	Manual Harvesting	Through Harvester		Manual Harvesting	Through Harvester	Manual Harvesting	Through Harvester
Weed management							
W_1:- Two hand weeding	30047	27808	86690	56643	67992	1.9	2.5
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	27653	25415	78299	50646	61369	1.8	2.4
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	28271	26033	85151	56880	67785	2.0	2.6
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	29184	26946	81420	52236	63439	1.8	2.4
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	29643	27405	83238	53595	65026	1.8	2.4
W_6:- Weedy check	22122	23293	25291	3170	9780	0.15	0.42
SEm±	--	--	1737	1737	1737	0.04	0.04
CD (P = 0.05)	--	--	5472	5472	5472	0.12	0.13
Seed rate (kg ha^{-1})							
S_1:- 80	28120	26450	72116	43996	54466	1.5	2.0
S_2:- 60	27820	26150	72143	44323	54693	1.5	2.1
S_3:- 40	27520	25850	75787	48267	58536	1.7	2.2
SEm±	--	--	877	878	852	0.03	0.03
CD (P = 0.05)	--	--	NS	NS	NS	NS	NS
Interaction (WM X SR)	--	--	NS	NS	NS	NS	NS

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