International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(4): 2054-2058

Received: 18-05-2018
Accepted: 19-06-2018

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Effect of weed management practices and seed rates on energy input, output, input output ratio, energy use efficiency and energy productivity on direct seeded rice production system

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Abstract
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. An experiment was conducted during *kharif* 2013 and 2014 with six weed management and three seed rates in *Inceptisols in* strip plot design. Rice variety MTU 1010 was taken as test crop. Result reveled that traditional *beushening* method proved significantly superior seed yield over other weed management practices (52.5 q ha^{-1}) was at par with the hand weeding twice (50.8 q ha^{-1}) and sequential application pre -emergence oxadiargyl 70 g ha^{-1}*fb* bispyribac Na @20 g ha^{-1} at 25 DAS (50.2 q ha^{-1}).Input energy was highest in *biasi* method (12.2 $MJX10^3$) followed by the hand weeding (11.9 $MJX10^3$). However, the weed management through herbicides shows low input energy as compared to the *biasi* method and hand weeding. The input energy was high in combine harvester as compared to manual harvesting system. Maximum output energy was recorded under the *biasi* method (152.7 $MJX10^3$) which was statistically superior over all the treatments. During the investigation seed rate does not influence the output energy and almost similar output energy was produced by the 120, 80 and 40 kg ha^{-1} seed rate. The maximum energy use efficiency (9.6) was recorded in withpre–emergence application of oxadiargyl 70 g ha^{-1}*fb*bispyribac Na @20 g ha^{-1} at 25 DASon mean basis. Efficiency of harvesting through harvester was less as compared to the manual harvesting but the difference was very marginal in both the years. However, harvester reduces the human energy in rice production system and promotes the timely operation. Energy productivity (.44kg MJ ha^{-1}) was recorded maximum in pre -emergence application oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS treatment which was at par with *biasi* method and hand weeding and other chemical control method. High energy productivity in combine harvester reveals the production of more yields per hectare by the expenditure of input energy, although the output input ratio and energy use efficiency was high in manual harvesting method.

Keywords: Broadcast direct seeded rice, seed rate, weed management, 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]. 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. 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) [5]. 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. 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*. Extremes from the recommended seed rate (i.e. too high or too low) 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.

Beushening is a traditional cultural practice of cross-ploughing in the dry-seeded broadcast standing crop after 25-35 DAS, followed by seedling redistribution through *Chalai* opration with the objective of weed management. Nowadays, due to the scarcity of the laborers and higher rate of wages, use of herbicide is becoming more popular. On the other hand, use of single herbicide alone does not serve the purpose and one hand weeding or mechanical weeding is essential for better weed management. To avoid hand weeding, sequential application of pre-emergence followed by post emergence herbicides will help in reducing the infestation of weeds throughout the growth period of broadcast direct seeded rice.

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]. It uses large quantities of locally available non-commercial energies, such as seed, farmyard manure and animate energy, and commercial energies directly and indirectly in the form of electricity, diesel fuel, chemical fertilizers, plant protections, irrigation water and farm machinery. The increased use of inputs such as fertilizer, irrigation water, diesel, plant protection chemicals, electricity etc. demands more energy in the form of human, animal and machinery.

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) [9]. 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. The aims of this study were to determine input energy, output energy and to investigate the 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 ricerainfall 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. Biasi* method (Farmer's practice), two hand weeding at 20 and 40 DAS, pre -emergence oxadiargyl 70 g ha^{-1}*fb*bispyribac Na @ 20 g ha^{-1} at 25 DAS, pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1}*fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS, (pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1}*fb* bispyribac Na 20g ha^{-1} at 25 DAS, weedy check and three seed rates ranging from *viz.*, 120, 80, and 40 kg ha^{-1} in horizonatal strips. 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 energetics of manual harvesting and harvesting through harvester primary data are used to calculate the energetics of rice production system through harvester, other operation are same in both the situation. By calculating both the harvesting system we can give the energy sustainable rice production system *i.e. "the machine to machine rice production system"*.

Energy inputs were calculated and estimated in Mega Joule (MJ) ha^{-1} with reference to the standard values prescribed by *Mittal et al.* (1985) [7]. 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. Energy use efficiency and Energy productivity were calculated as per the following formulae suggested by Singh and Mittal (1992) [8].

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

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

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

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, it is clear from the data that seed yield was significantly influenced by different weed management practices. Among different weed management practices, *biasi* method proved significantly superior seed yield over other weed management practices (52.5 q ha^{-1})was at par with the hand weeding twice(50.8 q ha^{-1}) and sequential application pre -emergence oxadiargyl 70 g ha^{-1}*fb* bispyribac Na @20 g ha^{-1} at 25 DAS(50.2 q ha^{-1}). The minimum seed yield was found in the weedy check treatment. Thakur *et al.* (2005) [10] also reported that the *biasi* method is best as compared to the *non-biasi* method. Walia *et al.* (2009) [12] and Kiran *et al.* (2010) [6] reported that the bispyribac-sodium is the best chemical for the direct seeded rice. With respect to different seeding rates, seed yield did not vary significantly. It showed that there is no remarkable yield difference between the high seed rate and low seed rate. However, seed yield was highest in 40 kg ha^{-1} seed rate followed by the 80 kg ha^{-1} and 120 kg ha^{-1} seed rate respectively. In respect to the mean data, the difference between the seed yield in seeding rates was very marginal. It was noticeable that the yield difference between 40 kg to 120 kg ha^{-1} was only 6 per cent. Data present in Table.1 reveals that with low seed rate and proper weed management, yield can be achieved as the tradition high seed rate. Same results were also observed by Yadav *et al.* (2007) [13] and Gill *et al.* (2007) [7] in their experimentation.

Table 1: Seed and straw yield, harvest index input, output energy of broadcast direct seeded rice as influenced by weed management and seed rate (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)		Total output energy ha^{-1} (MJ X10^3)
				Manually harvesting	Harvesting through harvester	
Weed management						
Biasi method (Farmer's practice)	52.2	59.7	46.8	12.2	12.8	152.7
Two hand weeding at 20 & 40 DAS	50.8	58.2	46.6	11.9	12.6	147.5
PE Oxadiargyl 70 g ha^{-1}*fb*Bispyribac Na @20 g ha^{-1} at 25 DAS	50.0	57.8	46.3	11.3	12.0	145.8
PE (Pretilachlor + Bensulfuron) 660 g ha^{-1}*fb*Bispyribac Na @ 20 g ha^{-1} at 25 DAS	46.1	55.9	45.3	11.4	12.1	137.6
PE (sand mix) Pyrazosulfuron 20 g ha^{-1}*fb*Bispyribac Na 20g h^{-1} at 25 DAS	47.8	57.8	45.3	11.4	12.0	142.5
Weedy check	11.5	38.6	22.5	11.0	12.0	65.2
SEm±	0.95	0.63	0.38	--	--	1.02
CD (P = 0.05)	2.10	1.98	1.20	--	--	3.22
Seed rate (kg ha^{-1})						
120	41.8	53.8	41.6	12.1	12.9	128.7
80	43.1	54.6	42.3	11.5	12.3	131.7
40	44.3	56.1	42.2	10.9	11.7	135.2
SEm±	0.36	0.31	0.18	--	--	0.77
CD (P = 0.05)	NS	NS	NS	--	--	3.02

Table 2: Effect of different weed management practices and seed rate on output-input ratio and energy productivity in broadcast direct 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})	
	Manually harvesting	Harvesting through Harvester	Manually harvesting	Harvesting through Harvester	Manually harvesting	Harvesting through Harvester
Weed management						
Biasi method (Farmer's practice)	12.6	11.9	9.3	8.8	0.43	0.43
Two hand weeding at 20 & 40 DAS	12.5	11.7	9.2	8.7	0.43	0.44
PE Oxadiargyl 70 g ha^{-1}*fb*Bispyribac Na @20 g ha^{-1} at 25 DAS	12.9	12.1	9.6	9.0	0.44	0.45
PE (Pretilachlor + Bensulfuron) 660 g ha^{-1}*fb*Bispyribac Na @ 20 g ha^{-1} at 25 DAS	12.1	11.4	9.0	8.4	0.40	0.41
PE (sand mix) Pyrazosulfuron 20 g ha^{-1}*fb*Bispyribac Na 20g h^{-1} at 25 DAS	12.6	11.9	9.3	8.8	0.42	0.43
Weedy check	6.0	5.5	4.6	4.2	0.11	0.08
SEm±	0.09	0.08	0.07	0.06	0.00	0.00
CD (P = 0.05)	0.08	0.26	0.21	0.19	0.01	0.01
Seed rate (kg ha^{-1})						
120	10.6	10.0	7.9	7.4	0.34	0.34
80	11.4	10.7	8.5	8.0	0.37	0.38
40	12.3	11.5	9.2	8.6	0.40	0.40
SEm±	0.07	0.26	0.05	0.05	0.00	0.00
CD (P = 0.05)	0.27	2.58	0.20	0.19	0.01	0.43

Straw yield

Straw yield significantly affected by different weed management practices. In respect to weed management practices, *biasi*method produced significantly higher straw yield, but it was found at par with treatments of two hand weeding and application of PE oxadiargyl 70 g ha^{-1}*fb* bispyribac Na @20 g ha^{-1} at 25 DAS and PE (sand mix) pyrazosulfuron 20 g ha^{-1}*fb* bispyribac Na 20g ha^{-1} at 25 DAS respectively. The lowest straw yield was observed under un-weeded control. The minimum yield of straw in control was due to more dry matter of weed and its density, or due to the high crop-weed competition which did not allow crop to grow with their genetic potential. The straw yield was statistically at par with each other in respect to the seeding method. However, the highest straw yield was found in 40 kg ha^{-1} seed rate followed by 80 kg and 120 kg ha^{-1} seed rate. This is due to the high plant to plant and weeds competition that did not allow the high dry matter production under 120 kg seed rate.

Harvest index

Harvest index is a measure of the productive efficiency of crop. Data of the harvest index also depicted significant response in relation to various treatments under study. Harvest index data revealed that different weed management practices significantly influenced the harvest index values. The significantly higher harvest index value was found under *biasi* method but it was at par with other weed management practices. The lowest harvest index value was recorded under un-weeded control. Different seeding rates did not affect harvest index significantly. However, crop sown with 40 kg ha^{-1} seed rate recorded maximum harvest index value (42.2) followed by 80 kg (42.3) and 120 kg ha^{-1} (41.6) seed rate on mean value basis.

Energy input output

The energy requirements for broadcast direct seeded rice cultivation under different treatments method using labour,

seed, fertilizer, herbicides etc. were estimated on the basis of standard energy coefficients (Mittal and Dhawan, 1988). Energy inputs required to the different treatments of weed management and seed rates were estimated. Input energy was highest in *biasi* method (12.2 $MJX10^3$) followed by the hand weeding (11.9 $MJX10^3$). However, the weed management through herbicides shows low input energy as compared to the *biasi* method and hand weeding. The input energy was high in combine harvester due to the use of heavy machine and high consumption of diesel as compared to manual harvesting system. However, the minimum energy required in weedy check method(11 $MJX10^3$) due to less labour required for harvesting and processing the produce. Maximum output energy was recorded under the *biasi* method (152.7 $MJX10^3$) which was statistically superior over all the treatments. Although, minimum output energy was recorded under the weedy check (62.2 $MJX10^3$). Due to weedy condition yield was very low in weedy check which reflects on output energy. As compared to the *biasi* method output energy was 134 per cent less in un-weeded control condition. This situation clearly indicates that the weeds are the major factor in production system. Energy was consumed by weed for their growth and development in place of rice plant. During the investigation seed rate does not influence the output energy and almost similar output energy was produced by the 120, 80 and 40 kg ha^{-1} seed rate. However, the maximum output was produced by the 40 kg ha^{-1} seed rate (135.2 $MJX10^3$) followed by the 80(131.7 $MJX10^3$) and 120 kg ha^{-1} seed rate (128.7 $MJX10^3$).

Energy output input ratio

Establishing the functional forms between energy inputs and output for agricultural crops are very useful in terms of determining elasticity of different energy inputs on yield (Turhan *et al*., 2008) [11]. Maximum energy output input ratio was observed in application of pre -emergence oxadiargyl 70 g ha^{-1} *fb*bispyribac Na @20 g ha^{-1} at 25 DAS (12.9). However, the minimum output-input energy was produced by weedy check (6.0). Output-input ratio was almost 110 per cent less in weedy check as compared to the *biasi*, hand weeding and chemical control. High output-input ratio in chemical control method supported the combination of herbicides and low seed rate might be the alternative of *biasi* and hand weeding method in broadcasting direct seeded rice.

Energy output-input ratio was less in combine harvester method of harvesting as compared to the manual harvesting, difference was only 5.5 to 6.5 per cent between the manual and combine harvester. However, difference was not very much in manual and harvester harvesting system, but in harvester timely harvesting of crop provides chance for timely sowing of next crop. Harvester may be the solution of labour crisis during the peak time of harvesting at village. Harvester saves the time of threshing and winnowing and other operation which required more energy in rice production system, this energy may be used for the next crop and other activity related to agriculture for high efficiency.

Energy use efficiency

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) [9]. Efficient use of energy resources in agriculture is one of the principal requirements for sustainable agricultural productions. Therefore, energy saving has been a crucial issue for sustainable development in agricultural systems. Development of energy efficient agricultural systems with low input energy compared to the output of food. The maximum energy use efficiency (9.6) was recorded in with pre-emergence application of oxadiargyl 70 g ha^{-1} *fb*bispyribac Na @20 g ha^{-1} at 25 DASon mean basis. All other weed management practices produced almost equal efficiency except the weedy check method which produced the minimum efficiency. Difference between the *biasi*, hand weeding and chemical control in respect to energy use efficiency was not very huge in respect to produce biological yield (q MJ ha^{-1}) by the unit input energy which supports chemical control might be the alternative of *biasi* and hand weeding in broadcasting direct seeded rice production system. Efficiency of harvesting through harvester was less as compared to the manual harvesting but the difference was very marginal in both the years. However, harvester reduces the human energy in rice production system and promotes the timely operation.

Energy productivity

Energy productivity is an important indicator for more efficient use of energy although higher energy productivity does not mean in general, more economic feasibility. Energy productivity (.44kg MJ ha^{-1}) was recorded maximum in pre-emergence application oxadiargyl 70 g ha^{-1} *fb*bispyribac Na @20 g ha^{-1} at 25 DAS treatment which was at par with *biasi* method and hand weeding and other chemical control method during the investigation. However, the energy productivity was higher in combine harvester as compared to the manual harvesting. High energy productivity in combine harvester reveals the production of more yields per hectare by the expenditure of input energy, although the output input ratio and energy use efficiency was high in manual harvesting method. This result supports the *"machine to machine rice production system"* in broadcasted direct seeded rice production system. *Biasi* method can be substituted by the combination of sowing by machine with low seed rate, application of herbicide and harvesting through the combine harvester for the double cropping system in Chhattisgarh. Timely operation by the involvement of machine in production system gives chance for the timely sowing of next crop.

Acknowledgment

The first author sincerely acknowledges Late Dr. A.P. Singh Professor Department of Agronomy for his guidance during investigation of research. The author also acknowledge Dr. S.V. Jogdand Professor and Dr. V.M. Victor Scientist Department of farm machinery and power engineering for their support to calculate the energy parameters.

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