Journal of Crop and Weed, 15(1): 121-126 (2019)

Influence of weed control techniques and establishment method on yield and economics of rain fed lowland rice

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Received : 20-04-2018 ; Revised : 11-12-2018 ; Accepted : 08-01-2019

ABSTRACT

A research was conducted at farmers' field at Imphal during kharif, 2015 and 2016 to determine the most profitable weed management against different crop establishment methods in lowland rice in Manipur. The highest rice grain yield (35.83 q ha^{-1}), weed control efficiency (72.42%), harvest index and all the yield contributing characters were recorded in two hand weeded plot but was statistically at par with pyrazosulfuron-ethyl @ 30g a.i. ha^{-1} with one hand weeding. Transplanted rice outperformed the two direct seeded rice (sprouted and dry seeding) in all respect but was uneconomical. Maximum weed index (73.40) was observed under transplanted rice with unweeded check and least with pyrazosulfuron-ethyl fb hand weeding showing as low as 6.16 %. Economically, direct sowing (sprouted seed) with pyrazosulfuron-ethyl fb one hand weeding was proved to be the most viable combination which also conforms to the principle of integrated weed management.

***Keywords*:** Economics, establishment method, integrated weed management, rice and yield

Rice (*Oryza sativa* L.) is a staple food crop in Manipur and 50% of the World's population. At least 114 countries grow rice and more than 50 countries have an annual production of 0.1 million ton (MT) or more (FAO, 2010). There are various methods of rice cultivation in Manipur viz, transplanted lowland (wet) puddled rice cultivation, low land puddle direct seeding (dry seed) etc. Productivity of the crop is low with high cost of production as it is grown as a mono crop with local practice of transplanting the seedlings on puddle soil that has been done from time immemorial. Labour intensive transplanting system has been opted by the farmers with direct seeding in many parts of the state. Owing to lack of data/information, the practice (DSR) could not be assumed to be more profitable than the normal transplanting method. On the other hand, the weed menace in DSR and its cost of management cannot be ignored considering the yield loss caused by the weeds. Direct seeding of rice (DSR) may involve sowing pre-germinated seed (sprouted) onto a puddled soil surface (wet seeding) or into shallow standing water (water seeding), or dry seed into a prepared seedbed (dry seeding). Direct seeding is increasingly replacing the traditional method of transplanting within dry-season irrigated rice production in the country. This change has been driven by increasing labour shortages, as members of the family farming unit move to off-farm employment in the larger provincial centres and through subsequent increases in the labour cost for transplanting. Direct seeding rice, a common practice before green revolution in India, is becoming popular once again because of its potential to save water and labour. This demands resurgence of physical, cultural and biological weed management, combined with judicious application of herbicides- known as integrated weed management (IWM) which utilizes resources and offers a wider range of management options.

MATERIALS AND METHODS

The Experiment was conducted at farmer's field in Manipur during *kharif*, 2015 and 2016. A total of fifteen treatments with various combinations of hand weeding, pre-emergence herbicide i.e. pyrazosulfuron ethyl (Saathi), post emergence herbicide 2,4-D and different crop establishment methods viz, dry direct seeding, sprouted direct sowing and transplanting. The treatment combinations were: T_1-DSR (dry seed)+2 HW; T_2- DSR (dry seed) +PE *fb* HW; T_3- DSR (dry seed)+POE *fb* HW; T_4- DSR (dry seed) + PE *fb* POE; T_5- DSR (sprouted seed)+ 2 HW; T_6- DSR (sprouted seed)+ PE *fb* HW; T_7- DSR (sprouted seed)+ POE *fb* HW; T_8- DSR (sprouted seed)+ PE *fb* POE; T_9-Transplanted rice +2 HW; T_{10}- Transplanted rice +PE *fb* HW; T_{11}- Transplanted rice + POE *fb* HW; T_{12}- Transplanted rice + PE *fb* POE; T_{13}- DSR (dry seed) unweeded; T_{14}- DSR (sprouted seed) unweeded; T_{15}- Transplanted rice unweeded (PE=Pre emergence herbicide {(pyrazosulfuron ethyl 10% (Saathi) @ 30 g *a.i.* ha^{-1})}; POE=Post emergence herbicide (2, 4-D Ester 38% EC @ 1 kg *a.i.* ha^{-1})*; DSR=Directed seed rice; HW=Hand weeding).*

The experiment was laid in a randomized block design with a plot size of 5m x 3m in three replications. The seed used was CAU R1 (Tamphaphou) variety. Direct seeding was done with two conditions i.e sprouted seed (soaking for 12 hrs) and non-soaking (dry seed). Nursery was made for transplanted treatments with 25

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days old seedling. The pre emergence herbicide used was Pyrazosulfuron ethyl @ 30 g *a.i.* ha^{-1}, 3 days after seed sowing for direct sowing (DSR) and transplanting on puddle moist soil for transplanted rice whereas, the post emergence herbicide used was 2,4-D (Ester) applied @ 1 *kg* ha^{-1} at 2-3 leaf stage of the weeds. Weeding (hand pulling) was done at 30 DAS and for treatments involving one hand weeding and 30 DAS and 50 DAT for two hand weeding, respectively. Seed sowing for DSR and transplanting of seedling was done on moist soil and the field was flooded to an adequate level after field emergence of DSR seeds and proper establishment of transplanted seedlings.

Soil samples were randomly collected to represent the whole field and analyzed for determining its physic-chemical properties as per standard procedures. The soil was clay loamy in texture with pH of 5.7, high in organic carbon (0.80%), moderate in available nitrogen (284 kg ha^{-1}), available P_2O_5 (15.5 kg ha^{-1}) and available K_2O (185 kg ha^{-1}). Data analyses were carried out by randomized complete block design (RCBD). Weed species count were taken and the dry weight recorded treatment wise and plot or replication wise. Weed samples were collected from each plot using a 50 cm quadrate. Species-wise count and dry weight were taken to calculate the Weed control efficiency (WCE) using the formula below:

$$WCE = \frac{\text{Dry wt. of weeds from control plot (g)} - \text{Dry wt. of weeds from treated plot(g)}}{\text{Dry weight og weeds from control plots}} \times 100$$

Harvest index, Weed index and economics of cultivation were calculated using the following formulae:

$$\text{Harvest index} = \frac{\text{Economic yield / grain yield}}{\text{Biological yield(Grain yield + straw yield)}} \times 100$$

$$\text{Weed index} = \frac{\text{Yield from weed free plot} - \text{yield from treated plot}}{\text{Yield from weedfree plot}} \times 100$$

Economics of cultivation was worked out based on the expenditures and incomes at prevailing local prices of inputs, labour charges and selling price of the grains and straws. Various economic calculation parameters were determined with formulae below:

Net return (Rs.**)** = Gross return-Total cost of cultivation

$$\text{Benefit-cost ratio} = \frac{\text{Gross return}}{\text{Total cost of cultivation}}$$

RESULTS AND DISCUSSION

Crop growth and yield attributes

Plants under transplanted method of crop establishment recoded tallest plants (123.90 cm) with two hand weeding. Individual effect on planting method when averaged revealed that there was statistically significant differences between transplanted rice and all the direct seeding in respect of plant height and other growth parameters (Table 1). Amongst the direct sowing methods (soaking, sprouted and dry seeds), there were also no significant differences in respect of growth characters. Wider and definite row spacing with adequate plant density better air, light and nutrition opportunities under transplanted condition might have attributed to taller plant heights and biomass. Maximum values of yield contributing characters viz, effective tillers $plant^{-1}$ (20.00), panicle length (27.33 cm), filled grains/panicle (175.13) and test weight (50.07 g) showed similar trends of better performance under transplanted conditions with two hand weeding than all other treatments (Table 2). All the treatments were found to be significantly higher in plant growth and yield attributes over untreated checks. Two hand weeding outperformed the rest of treatments in growth and yield attributes as also reported by Bhat *et al.* (2017).

Grain, straw yield and harvest index

The highest rice grain yield (35.83 qha^{-1}) was recorded in two hand weeding under transplanted condition followed by integration of pyrazosulfuron-ethyl (PE)and one hand weeding under sprouted condition of DSR (34.07 q ha^{-1}). However, the two treatments were statistically at par with pyrazosulfuron-ethyl (PE) *fb* one HW (33.27 q ha^{-1}) under transplanted condition (Table 2). Similar finding was also reported by (Chopra and Chopra, 2003). The increase in grain yield under this treatment might be due to less weed density and weed biomass as compared to all other treatments under study. Lowest grain yield of rice was observed in untreated checks (dry DSR, sprouted DSR and transplanted rice) which might be due to dominance of aggressive weeds over crop (Table 3). Similar trends of straw yield was observed where performance of two weeding under transplanted condition recorded highest values (53.83 q ha^{-1}) with lowest straw yields under

Tables 1: Effect of weed management practices and different establishment methods on the growth parameters and yield attributes of rice

Treatment	Effective tillers plant^{-1}	Panicle length (cm)	Filled grains panicle^{-1}	Spikelet panicle^{-1}	Test weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	HI (%)	Gross Income (Rs. x^{1000})	Net return (Rs. x^{1000})	B:C
T1	12.33	23.13	111.67	18.53	44.50	26.03	44.03	37.14	60.87	16.55	1.37
T2	10.00	21.83	119.55	16.90	45.50	25.77	43.77	37.04	60.29	24.25	1.67
T3	12.33	23.13	118.27	13.83	41.50	21.67	39.67	35.28	51.27	15.07	1.42
T4	12.33	19.33	109.33	13.87	39.33	24.39	42.30	36.52	57.06	29.16	2.04
T5	16.00	25.57	131.90	15.87	45.27	28.87	46.80	38.12	66.96	22.41	1.50
T6	11.00	24.83	126.33	14.23	42.93	34.07	44.07	39.55	78.29	42.03	2.41
T7	12.67	22.97	125.00	13.87	45.30	32.15	44.10	39.06	72.82	36.40	2.00
T8	11.67	19.90	110.00	16.17	34.03	29.88	41.43	38.40	67.89	39.76	2.16
T9	20.00	27.33	175.13	18.57	50.07	35.83	53.83	39.92	82.43	33.16	1.67
T10	18.33	20.37	164.93	13.57	46.87	33.27	51.27	39.34	76.79	35.80	1.87
T11	17.33	18.41	154.03	14.47	43.03	32.07	50.07	39.03	74.15	33.00	1.80
T12	11.00	18.23	152.43	13.73	45.10	30.03	48.03	38.40	69.61	36.76	2.12
T13	5.00	16.27	79.33	7.90	29.93	8.50	28.53	24.27	18.25	-3.13	0.85
T14	7.00	17.27	85.33	8.20	31.90	9.40	31.00	25.52	19.90	-1.70	0.92
T15	9.33	16.83	94.67	8.50	36.20	10.91	30.97	27.38	22.40	-4.60	0.83
SEm (±)	**0.908**	**1.260**	**3.566**	**0.906**	**1.234**	**1.082**	**1.117**	**0.388**			
LSD (0.05)	**2.645**	**3.668**	**10.383**	**2.638**	**3.594**	**3.150**	**3.252**	**1.128**			

Note: T1-DSR (dry seed)+2 HW; T2- DSR (dry seed) +PE fb HW; T3- DSR (dry seed)+POE fb HW; T3- DSR (dry seed)+POE fb HW; T4- DSR (dry seed) + PE fb POE; T5- DSR (sprouted seed)+ 2 HW; DSR (sprouted seed)+ PE fb HW; T7- DSR (sprouted seed)+ POE fb HW; T8- DSR (sprouted seed)+ PE fb POE; T9- Transplanted rice +2 HW; T10- Transplanted rice +PE fb HW; T11- Transplanted rice + POE fb HW; T12- Transplanted rice + PE fb POE; T13- DSR (dry seed) unweeded; T14- DSR (sprouted seed) unweeded; T15- Transplanted rice unweeded

Tables 2: Effect of weed management practices on the weed count, total weed dry weight, weed control efficiency and weed index under different rice stablishment methods

Treatment	Weed count (No.m^{-2})			Total weed DW	WCE	W.I.
	Sedges	BLWs	Grasses	(g m^{-2})	(%)	(%)
T1	4.16 (16.30)	3.41 (10.67)	3.96 (14.67)	5.67 (31.63)	64.28	0.00
T2	4.16 (16.33)	2.81 (7.00)	4.07 (15.57)	5.45 (29.23)	65.87	11.02
T3	4.28 (17.33)	3.60 (12.00)	4.31 (17.57)	6.11 (36.90)	58.34	16.77
T4	4.20 (16.67)	3.92 (14.33)	4.16 (16.33)	6.15 (37.33)	57.85	6.66
T5	4.04 (15.33)	3.82 (13.67)	3.69 (12.67)	5.66 (31.67)	63.45	0.00
T6	4.04 (15.33)	3.31 (10.00)	3.90(14.23)	5.47 (29.57)	66.99	9.49
T7	4.11 (16.00)	4.08 (15.67)	3.78 (13.30)	5.95 (34.97)	59.64	9.38
T8	4.27 (17.27)	3.87 (14.00)	3.86 (14.00)	5.97 (35.27)	59.29	18.63
T9	3.85 (14.33)	2.88 (7.33)	3.26 (9.67)	4.72 (22.00)	72.42	0.00
T10	4.43 (18.67)	3.78 (13.33)	4.38 (18.20)	6.37 (40.20)	60.60	6.16
T11	4.20 (16.67)	4.16 (16.33)	3.34 (10.20)	5.80 (33.20)	58.38	10.51
T12	4.40 (18.33)	3.87 (14.00)	3.66 (12.47)	5.94 (34.80)	56.37	16.19
T13	5.59 (30.33)	5.16 (25.67)	6.60 (42.57)	9.44 (88.57)	-	67.35
T14	5.60 (30.33)	5.41 (28.33)	6.24 (37.97)	9.33 (86.63)	-	67.36
T15	6.18 (37.33)	5.22 (26.33)	5.20 (26.10)	8.94 (79.77)	-	73.40
SEm (±)	**0.445**	**0.136**	**0.127**	**0.201**	**-**	**-**
LSD (0.05)	**0.153**	**0.397**	**0.368**	**0.585**	**-**	**-**

Note: Data were subjected to square root transformation (X + 0.5), Values within parentheses are original

T1-DSR (dry seed)+2 HW; T2- DSR (dry seed) +PE fb HW; T3- DSR (dry seed)+POE fb HW; T3- DSR (dry seed)+POE fb HW; T4- DSR (dry seed) + PE fb POE; T5- DSR (sprouted seed)+ 2 HW; DSR (sprouted seed)+ PE fb HW; T7- DSR (sprouted seed)+ POE fb HW; T8- DSR (sprouted seed)+ PE fb POE; T9-Transplanted rice +2 HW; T10- Transplanted rice +PE fb HW; T11- Transplanted rice + POE fb HW; T12- Transplanted rice + PE fb POE; T13- DSR (dry seed) unweeded; T14- DSR (sprouted seed) unweeded; T15- Transplanted rice unweeded

untreated DSRs and transplanted rice. Harvest index of the crop was highest under two hand weeding in transplanted rice (39.92%) which was comparable with Sprouted DSR subjected to pyrazosulfuron-ethyl (PE) *fb* HW, transplanted rice with pyrazosulfuron-ethyl (PE) *fb* HW and Sprouted DSR with 2, 4-D (POE) *fb* HW (35.28 %). Lowest harvest index (24.27%) was recorded under untreated DSR (dry seeds). Under transplanted condition, lowest weed index (6.16%) was associated with pyrazosulfuron-ethyl (PE) *fb* HW whereas under DSR, the lowest weed index was recorded with DSR (dry seed) subjected to pyrazosulfuron-ethyl (PE) *fb* HW (11.02%). Comparison between the weed index of DSR and transplanted rice, less grain loss due to weeds could be established under transplanted condition over the DSR. Lower weed density, higher WCE and better spaces between the plants could be attributed to this fact. Pal *et al*. (2012) also reported that pyrazosulfuron-ethyl 70% WG at 42.0 gha^{-1} applied at 3 DAT was most effective in managing associated weed species and yielded maximum grain yield (3.3 t ha^{-1}) of rice with lower weed index (10.8%). Better performance of rice grain yield with the inclusion of pyrazosulfuron-ethyl @ 25g ha^{-1} was also reported by Teja *et al.* (2017) in transplanted rice.

Weed spectrum, density and biomass

The major weed florain the field were, *Echinochloa spp*., *Ischaemum rugosum, Cyperus difformis and Fimbristylis miliacea, Monochoria vaginalis, Eclipta alba, Cynodon dactylon etc.* All the herbicides showed effective control of all categories of dominant weeds under all establishment methods resulting in less weed count and dry matter as compared to untreated check. Sedges were best controlled by hand weeding under transplanted condition and were significantly effective over rest of the treatments. The effect was however non-significant amongst the DSR (sprouted) subjected to two hand weeding and pre emergence application of pyrazosulfuron-ethyl followed by one hand weeding. Similar trends were observed in DSR (dry seeding) and between the two seeding methods under unweeded condition (Table 2). Angiras and Kumar (2005) also found similar results. The number of dominant broad-leaved and weed biomass was comparatively less with pyrazosulfuron-ethyl followed by hand weeding that was statistically at par with Transplanted rice with 2 HW. The two treatments were however, significantly effective as compared to all the treatments. The number of BLWs under unweeded conditions in all the establishment methods were also found to be significant with DSR (dry seeding) showing maximum weed number followed by transplanted and DSR (sprouted), while, grass and sedge weeds were effectively controlled with two hand weeding at 30 DAS and 50 DAT. The result also revealed that all the treatments gave significant control of weed population.

Weed control efficiency

The results revealed that all the treatments gave significant control of weed population. However, the highest weed control was given by twice manualha-1nd weeding under transplanting condition (72.42%) closely followed by DSR (sprouted seed) + PE *fb* HW (66.99%). The result is corroborated by Hussain *et al*. (2008) with two handing in rice giving highest weed control efficiency. Since sedges and broadleaved weeds were dominant weeds, hand weeding twice was effective for controlling all the weed species under transplanted condition whereas, pre emergence herbicide (pyrazosulfuron-ethyl) followed by one hand weeding took care of the broadleaved weeds more effectively under direct seeding method. Hence, these two could have reduced the weed population to a remarkable extend leading to highest control efficiencies. The higher WCE of transplanted rice may be due to cleaner plots and hassle free weeding by manual means. Better performance of the treatment, DSR (sprouted seed) + pyrazosulfuron-ethyl (PE) *fb* HW may be due to the effective control of BLWs by the pre emergence herbicide and the grasses and sedges by manual weeding. The findings are also in agreement with Rekha *et al.* (2002) who reported that twice hand weeding resulted in lower weed density compared to weedicides and untreated control. Halder *et al.* (2005) also reported highest weed control efficiency of 78 % with the application of pyrazosulfuron ethyl in boro rice.

Economics

Economic analyses revealed that the highest net returns and benefit cost ratio (Rs. 42030 and 2.41 respectively) were recorded in DSR (sprouted seed) treated with pyrazosulfuron-ethyl (PE) *fb* HW followed by pyrazosulfuron-ethyl (PE) *fb* 2,4-D (POE) (Rs.39757 ha^{-1}) under the same establishment method (Table 5). All the three untreated checks showed negative values of net benefits. Though the grain yield was highest under transplanted rice with two hand weeding, the operation is tedious and highly labor intensive and thus it is not an economically viable option for the farmers. Similar finding was reported by Trung *et al.* (1995) and Roder (2001). Amongst the DSRs, the treatment with pyrazosulfuron-ethyl (PE) followed by 2,4-D (POE) was found to be effective (BCR:2.04) and could be the next possible option whereas, under transplanted condition too, the highest BCR (2.12) was associated with the two chemical herbicides in sequential application.

From the results achieved, it can be concluded that the highest rice grain yield was recorded in two hand weeding treatment which was statistically at par with pyrazosulfuron-ethyl @ 30 g *a.i.* ha^{-1} application with one hand weeding. However, in the economic aspect, this treatment was associated with maximum expenses due to high labour involvement and subsequently high cost. Hence, the treatment, pyrazosulfuron-ethyl @ 30g *a.i.* ha^{-1} followed by one hand weeding proved to be the most viable treatment as the integrated weed management would also reduce the use of chemical herbicide and hence, save the environment to some extent.

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