Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(4): 430-433
Received: 26-05-2019
Accepted: 27-06-2019

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Yield and economics of rice (*Oryza sativa* L.) as influenced by crop establishment methods and weed management practices

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Abstract
In Kashmir valley the shortage of labour and water are pressing farmers to explore the alternatives of conventional transplanting. A field experiment was conducted during *kharif* seasons of 2017-2018 at SKUAST-K, Wadura, Sopore Jammu and Kashmir, to evaluate the performance three crop establishment methods (M_1-Transplanting (TPR), M_2-Direct Seeding (DSR), M_3-System of Rice Intensification (SRI) and seven weed management practices in sub plots (w_1-Butachlor, w_2-Penoxsulam (22.5 g *a.i.* ha^{-1}), w_3-Pyrazosulfuran ethyl + pretilachlor (15 and 600 g *a.i.* ha^{-1}), w_4- Bensulfuron methyl + pretilachlor (60 and 600 g *a.i.* ha^{-1}), w_5-Twice conoweeding/hand weeding, W_6-Weed free and w_7-Weedy check) on rice yield and economics. The treatments were replicated thrice in a split plot design. The data revealed that crop establishment methods and weed management practices significantly influenced the grain and straw yield and economics of rice. SRI method of crop establishment had resulted in significantly higher rice grain and straw yield over direct seeding and transplanted rice. Among the weed management practices, application of penoxsulam (22.5 g *a.i.* ha^{-1}) produced significantly higher grain and straw yield compared to other practices. Average grain yield increase with SRI was 16.66 and 18.19 % and 7.5 and 9.43 % over direct seeding and transplanting during 2017 and 2018, respectively. Highest B: C ratio of 1.60 was recorded under SRI with the application of penoxsulam (22.5 g *a.i.* ha^{-1}).

Keywords: Direct seeding, SRI, transplanting, weed management, conoweeding, hand weeding

Introduction
Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population including regions of high population density and rapid growth. It provides about 21 per cent of the total calorie intake of the world population. In India, rice occupies about one-quarter of the total cropped area, contributes about 40 to 43 percent of total food grain production, providing direct employment to 70 per cent rural population and plays a vital role in national food and livelihood security (DES, 2013) [2]. In Jammu and Kashmir, rice is cultivated on an area of about 0.26 million hectares producing 0.55 million tonnes of grain with a productivity of 2.1 tonnes per hectare, (DES, 2013) [2]. In India rice is grown in about 45 million hectares with a production of about 92 million tonnes. In Jammu and Kashmir, State the rice crop occupies an area of 2.65 lakh hectares with a production of around 454.8 thousand tones out of which Kashmir valley alone accounts for 62 per cent of the production (DES, 2015) [3]. Transplanting is the most dominant method of rice establishment in Kashmir valley. The area under transplanted rice in world is decreasing due to scarcity of water and labour. So, there is need to search for alternate crop establishment methods to increase the productivity of rice (Farooq *et al*., 2011) [4]. Direct seeding reduces labour requirement, shortens the crop duration by 7-10 days and can produce as much grain yield as that of transplanted crop. Pandey and Valesco (2005) [10] advocated that transplanted rice be practiced in areas where low wages for labour and adequate water is available whereas, direct seeded rice can be practiced in areas with high wages and low water availability. The system of rice intensification was recently promoted as an alternative technology and resource management strategy for rice cultivation that offers the opportunity to boost rice yields with less external inputs. The system of rice intensification consists of a set of management practices that were mainly developed through participatory approach (on-farm experiments) in the central highland of Madagascar in the 1980s (Stoop *et al*., 2002) [15]. The basic components of SRI as promulgated by Father Henry D. Laulanea of Madagaskar are transplanting of single, widely spaced, young seedlings below 15 days age, mechanical weeding with a rotary push weeder that aerates the soil and controls weeds, water management in such a way that there is no continuously standing water during the vegetative growth phase, and reliance on compost as far as possible, with supplemental or no use of

chemical fertilizer. In areas with scarcity of water and labour, transplanting can be replaced by direct seeding under puddle condition and SRI (Parameswari *et al.*, 2014) [11]. Weed competition is going to be the major constraint in achieving higher productivity. Weed control is major prerequisite for improved rice productivity and production in all of the rice establishment methods. Weed infestation in rice has been established as one of the important factors responsible for lower productivity as the weed flora under transplanted conditions cause a yield reduction upto 45 per cent (Manhas *et al.*, 2012) [8]. Out of the losses due to various biotic stresses, weeds are known to account for 45 per cent of the losses. The effective control measures at initial stage of crop growth can help in improving the productivity of rice. Although a number of pre-emergence herbicides provide good control of grassy weeds but due to continuous use of such herbicides a shift in weed flora and evolution of herbicide resistant weeds has been observed (Rajkhowa *et al*, 2006) [12].

Material and Methods

The field experiment was conducted to study the yield and economics of rice as influenced by crop establishment methods and weed management practices under the temperate conditions of Kashmir valley at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura Sopore, Jammu and Kashmir during *kharif* 2017 and 2018. The soil of experimental field was silty clay loam in texture, neutral in reaction (pH 6.9), medium in available N, P and K with medium organic carbon content. The treatments consisted of three crop establishment methods (M_1-Transplanting (TPR), M_2-Direct Seeding (DSR), M_3-System of Rice Intensification (SRI) in main plots and seven weed management practices in sub plots (w_1-Butachlor, w_2-Penoxsulam (22.5 g *a.i.* ha^{-1}), w_3-Pyrazosulfuran ethyl + pretilachlor (15 and 600 g *a.i.* ha^{-1}), w_4- Bensulfuron methyl + pretilachlor (60 and 600 g *a.i.* ha^{-1}), w_5-Twice conoweeding/hand weeding, W_6-Weed free and w_7-Weedy check). The treatments were replicated thrice in a split plot design. For SRI method, 12 day old seedlings (of variety Shalimar Rice-4) were transplanted in last week of May at a spacing of 25 cm x 25 cm during both the years of experimentation. For direct seeded rice (DSR)) the pre-germinated seeds were sown in rows 20 cm apart in well prepared plots on 17th May while for transplanting (TPR) nursery sowing was done with same pre-germinated seeds on the same date and then 25 day old seedlings were transplanted at a spacing of 20 x 10 cm. Well decomposed farm yard manure @ 10 t ha^{-1} was incorporated in treatment plots uniformly during land preparation. In the nutrient management treatments (inorganics) the entire quantity of phosphorus and potassium and half of nitrogen was applied as basal at the time of transplanting while remaining N was applied in two equal splits at active tillering and panicle initiation stages. Under SRI method all the principles were followed. Water management in both SRI and DSR was done in such a way that there is no continuously standing water during the vegetative growth phase while thin film of water was maintained during flowering to soft dough stage. Under TPR, plots were flooded with water. Liquid herbicides as per treatments were applied with knapsack sprayer fitted with flat fan nozzle using 300 liters of water ha^{-1} whereas the granular herbicides were mixed with sand and applied uniformly across the plot. Grain and straw yield was recorded at maturity. The crop was harvested during 2nd week of October in both the years. The economics was worked out taking into consideration, the cost of production for each treatment, the corresponding marketable yield with prevalent prices per unit output.

Result and Discussion

Grain and straw yield of rice differed significantly during both the years of experimentation (Table 1). SRI method of crop establishment recorded significantly higher grain yield (7.92 t ha^{-1} and 8.17 t ha^{-1}) and was followed by transplanting (7.09 t ha^{-1} and 7.17 t ha^{-1}). Lowest grain yield of 6.01 and 6.24 t ha^{-1} was noticed in case of DSR. The crop established by SRI method provided a mean yield advantage of 7.5 and 16.66 % during 2017 and 9.43 and 18.19 % during 2018, respectively over transplanting and direct seeding. Hugar *et al.* (2009) [5] also reported higher grain yield of rice under SRI from Bhadra command area in Karnataka. SRI method also recorded significantly higher straw yield than DSR and normal transplanting. The higher grain and straw yield realized with SRI method may be due to transplanting of seedlings at younger age which preserves a potential for more tillering and rooting. Further, wider spacing in square pattern (25 cm x 25 cm) provides more room for both canopy and root growth and for subsequent grain filling. The increase in the grain yield under SRI method was attributed to larger root volume, profuse and strong tillers with longer panicles, more and well filled spikelets with higher grain weight. Comparable yields in rice through alternate systems of crop establishment with that of transplanting has been reported by Mankotia *et al.* (2009) [9] and Mahajan *et al.* (2012) [7].

Different weed management practices had a significant impact on grain and straw yield during both the years. Higher grain yield (9.0 and 9.29 t ha^{-1}) was recorded by weed free treatment which was significantly superior to weedy check and other weed control treatments. Among the different herbicides used, penoxsulam @ 22.5 g *a.i.* ha^{-1} provided significantly higher grain yield over weedy check and other weed control treatments, during both the years. Penoxsulam @ 22.5 g *a.i.* ha^{-1} realized 26.25 and 22.34 %, 7.32 and 6.15 %, 11.23 and 10.02 %, 13.79 and 13.76 % and 49.93 and 46.98 % more grain yield as compared to butachlor (1500 g *a.i.* ha^{-1}), pyrazosulfuron ethyl + pretilachlor (15 and 600 g *a.i.* ha^{-1}) and bensulfuron methyl + pretilachlor (60 and 600 g *a.i.* ha^{-1}), twice cono weeding/hand weeding and weedy check, during 2017 and 2018 respectively. This could be attributed to the fact that reduction in weed growth with the herbicide application allowed the crop to get adequate nutrient supply resulting in higher leaf-area index and thus more photosynthates, which in turn contributed to the sink resulting in higher grain and straw yield. These results are in line with Shan *et al.* (2012) [14] and Jabran *et al.* (2012) [6].

The pooled data on economic analysis of treatments is presented in Table 2. It is evident from the pooled data that apart from weed free treatment highest gross returns (Rs.217159.3) and net returns (133769.3) were realized under SRI with the application of penoxsulam (22.5 g *a.i.* ha^{-1}) during both the years. The highest B: C ratio was also provided with the same combination (1.60) and the lowest B: C ratio (0.32) was realized by the combination of direct seeding with weedy check, respectively. This might be due to the fact that among crop establishment methods, SRI can increase yield because of higher water infiltration and storage capacity and less erosion (Shao-hua *et al*., 2002) [16] that results in maximum benefit contributing higher benefit cost ratio (Ranjitha *et al*., 2014) [13], while as among different herbicides used penoxsulam @ 22.5 g *a.i* ha^{-1} provided nearly a weed free situation at the critical growth stages of crop and enhanced the competitive ability of the rice crop. The results are in line with that of Bhat *et al*. (2011) [1].

Table 1: Yield of rice as influenced by crop establishment methods and weed management practices

Treatments	Grain yield (t ha^{-1})		Straw yield (t ha^{-1})	
	2017	2018	2017	2018
Crop establishment methods				
Transplanting	7.09	7.17	8.88	9.21
Direct Seeding	6.01	6.24	8.00	8.32
System of rice intensification	7.92	8.17	9.60	10.17
SE(m) ±	0.25	0.28	0.26	0.29
C.D. ($p \leq 0.05$)	0.75	0.84	0.79	0.87
Weed management practices				
Butachlor (1500 g *a.i.* ha^{-1})	6.04	6.43	8.23	8.67
Penoxsulam (22.5 g *a.i.* ha^{-1})	8.19	8.28	10.13	10.44
Pyrazosulfuron-ethyl + Pretilachlor (15 and 600 g *a.i.* ha^{-1})	7.59	7.77	9.31	9.51
Bensulfuron-methyl + Pretilachlor (60 and 600 g *a.i.* ha^{-1})	7.27	7.45	9.03	9.37
Twice Conoweeding/handweedig (15 and 30 DAS/DAT)	7.06	7.14	8.72	8.96
Weed free	9.00	9.29	10.75	11.19
Weedy check	4.10	4.39	6.06	6.50
SE(m) ±	0.24	0.28	0.23	0.21
C.D. ($p \leq 0.05$)	0.72	0.84	0.69	0.61

Table 2: Economics of rice as influenced by crop establishment methods and weed management practices (pooled over two years)

Treatment combinations	Total cost of cultivation (Rs.)	Gross returns from grain yield (Rs.)	Gross returns from straw yield (Rs.)	Total returns (Rs.)	Net returns (Rs.)	B:C ratio
M_1W_1	77615	80270.67	84006	164276.7	86661.67	1.12
M_1W_2	79165	107978.00	94449	202427	123262	1.56
M_1W_3	78735	103688.00	91635	195323	116588	1.48
M_1W_4	78735	99792.33	88725	188517.3	109782.3	1.39
M_1W_5	81465	95740.67	85911	181651.7	100186.7	1.23
M_1W_6	85465	111583.33	97275	208858.3	123393.3	1.44
M_1W_7	77465	54340.00	52941	107281	29816	0.38
M_2W_1	69715	67682.33	75411	143093.3	73378.33	1.05
M_2W_2	71265	95355.00	84897	180252	108987	1.53
M_2W_3	70835	91303.33	82077	173380.3	102545.3	1.45
M_2W_4	70835	87247.33	80175	167422.3	96587.33	1.36
M_2W_5	73565	83217.33	77331	160548.3	86983.33	1.18
M_2W_6	77565	99645.00	84690	184335	106770	1.38
M_2W_7	69565	46345.00	45390	91735	22170	0.32
M_3W_1	81840	87351.33	91794	179145.3	97305.33	1.19
M_3W_2	83390	115834.33	101325	217159.3	133769.3	1.60
M_3W_3	82960	112298.33	98559	210857.3	127897.3	1.54
M_3W_4	82960	107835.00	95763	203598	120638	1.45
M_3W_5	85690	103848.33	93039	196887.3	111197.3	1.30
M_3W_6	89690	119946.67	134355	254301.7	164611.7	1.84
M_3W_7	81690	66711.67	61695	128406.7	46716.67	0.57

Conclusion

The results indicated that SRI proved to be better than transplanting and direct seeded rice in terms of yield and relative economics. Among different weed management practices, penoxulam @ 22.5 g *a.i.* ha^{-1} proved to be most efficient in in terms of yield attributes, grain yield and relative economics. These findings led to the conclusion that for realizing higher and sustainable yield of rice under temperate conditions of Kashmir Valley, system of rice intensification proved to be better method of crop establishment and the application of penoxulam @ 22.5 g *a.i.* ha^{-1} should centre efficient weed management in rice crop.

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