

Effect of water regimes and weed-management practices on growth, yield and weed-control efficiency of rice under system of rice intensification

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2012 and 2013 at Khudwani, Jammu and Kashmir, to evaluate the effect of water regimes and weed-management practices on growth and yield of rice (*Oryza sativa* L.) grown on silty clay loam soil. The treatments comprised 3 irrigations schedules, viz. alternate wetting and drying (AWD), saturated conditions (SC) and continuous flooding (FL), and 7 weed-management options including 4 herbicidal treatments, viz. pyrazosulfuron ethyl @ 20 g/ha at 3 days after transplanting (DAT, W₁); cyhalofop butyl @ 80 g/ha at 15 DAT (W₂); pyrazosulfuron ethyl 20 g followed by (fb) cyhalofop butyl 80 g/ha at 3 and 15 DAT (W₃); butachlor @ 1.5 kg/ha at 3 DAT (W₄); 3 cono weeding at 15, 25 and 35 DAT (W₅) along with weedy check (W₆) and weed free (W₇). The experiment was laid out in a split-plot design with 3 replications under SRI. The data revealed that significant higher growth parameters like leaf-area index (LAI), dry-matter accumulation and tillers/plant and yield attributes, i.e. panicle length, panicles/m², grains/panicle, panicle weight, grains/panicles, 1,000-grain weight, and higher grain yield were recorded in saturated water regime. On an average a yield superiority of 2.2 and 5.8% was recorded by saturated water regime over AWD and continuous flooding. Among the herbicides tested, pyrazosulfuron-ethyl @ 20 g/ha (3 DAT) fb cyhalofop-butyl @ 80 g/ha (15 DAT) resulted in significantly higher panicle length, panicles/m², panicle weight, grains/panicles, 1,000-grain weight and higher grain yield comparable to the weedy check. The mean yield advantage recorded by the use of pyrazosulfuron-ethyl fb cyhalofop-butyl was 19.3, 14.0 and 10.3% over cyhalofop-butyl, cono-weeding and butachlor, respectively, during both the years of experimentation.

Key words : Grain yield, Pyrazosulfuron-ethyl, Rice, SRI, Water regimes, Weed management,

Rice is the premier food crop of India and therefore, national food security system largely depends on the productivity of rice in different ecosystems. Among the rice-growing countries, India stands first in area [36.95 million ha (mha)] and second in production (120.6 mt) next only to China. However, the average productivity of rice in India is only 2.41 t/ha against the global average of 4.37 t/ha (FAO STAT, 2015). In Jammu and Kashmir State, the rice crop is cultivated over an area of 274,000 ha, with a production of around 904,400 tonnes and a productivity of 3.24 t/ha (DES, 2015).

The existing system of rice production, particularly green revolution technology is input intensive and favours cash rich farmers. Increasing prices of agricultural inputs

prevent poor farmers from completely adopting modern production technologies (Stoop *et al.*, 2002). In order to improve resource-use efficiency, it is necessary to address the growing concerns regarding water scarcity, higher fertilizer costs and negative environmental impacts due to the increasing use of agrochemicals for rice production. In such a situation, the system of rice intensification (SRI) has been promoted to as an alternative technology and resource-management strategy for rice cultivation that may offer the opportunity to boost rice yields with less external inputs (Uphoff and Randriamiharisoa, 2002). The main elements of SRI include 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 through alternate wetting and drying and reliance on compost as far as possible, with supplemental or no use of chemical fertilizer. When rice fields are not flooded continuously and plants are

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widely spaced as recommended under SRI, weeds get a better chance to grow. Therefore, efficient weed-management practices are required under SRI. The higher amount of labour for weeding is one of the most limiting aspects of SRI. Therefore, it is essential to control weeds in rice fields for the greater utilization of growth factors by the crop to get higher yield. When fields are not kept continuously flooded, weed growth becomes a challenging problem, and farmers use excess water to check weed growth and to reduce their labour requirements for weed control. Weeding can be quite labour demanding, but its timing is more flexible than in transplanting. So, weeding is a deterrent to SRI adoption (Satyanarayana *et al.*, 2007). Herbicides have been introduced as they are efficient, practical and cost-effective particularly in areas where labour is scarce or expensive. While capitalizing on the other practices and efforts have to be made for evaluating the alternative efficient and cost-effective weed-management practices.

The Kashmir valley with temperate climate has a unique set of varieties suited to its agro-climatic situation. In spite of this fact the average yields (3.23 t/ha) are far below the potential yields (9 t/ha) due to the several constraints, the main among them being weed infestation, poor water management and poor adoption of new technologies. Therefore, appropriate irrigation water management and cost-effective and consistent weed-management system need to be evaluated and identified for the system of rice intensification. A study was carried out to find out the effect of water regimes and weed-management practices on rice in system of rice intensification under Kashmir Valley conditions.

MATERIALS AND METHODS

A field experiment was conducted at Mountain Research Centre for Field Crops, SKUAST-Kashmir, Khudwani (33°43' N, 75°5' E and 1,596 m above mean sea-level). The site falls in mid-altitude temperate zone characterized by hot summers and very cold winters with an average annual precipitation of 812 mm (average of past 20 years). The experiment was conducted during the rainy (*kharif*) seasons of 2012 and 2013 on silty clay loam soil, neutral in pH (6.78), low in available nitrogen (215 kg/ha), medium in available phosphorus (15.0 kg/ha) and potassium (205 kg/ha). The rainfall received during crop-growing season, extending from May to October for 2012 and 2013 was 32 mm and 60 mm respectively.

The experiment comprised 3 water regimes, viz. alternate wetting and drying (AWD), saturated conditions (SC) and continuous flooding (FL), and 7 weed-management practices including 4 herbicidal treatments, viz. pyrazosulfuron ethyl @ 20 g/ha at 3 DAT (W_1); cyhalofop

butyl @ 80 g/ha at 15 DAT (W_2); pyrazosulfuron ethyl 20 g/ha cyhalofop butyl 80 g/ha 3 and 15 DAT (W_3); butachlor @ 1.5 kg/ha at 3 DAT (W_4); 3 cono weeding at 15, 25 and 35 DAT (W_5) along with weedy check (W_6) and weed-free (W_7). The experiment was laid out in split-plot design with 3 replications. Transplanting was carried out during the 1st week of June, during both the years with 1 seedling of 14 days old/hill, transplanted in a square pattern at 25 cm × 25 cm spacing. Marked ropes at equal distances were used to achieve square planting. All the plots received uniform dose of 120 kg N/ha, 60 kg P_2O_5 /ha and 30 kg K_2O /ha + FYM @ 10 t/ha was incorporated at the time of layout of experiment. Whole amount of P and K and half of N were applied basal dose before transplantation. The remaining N was applied in 2 equal splits—at tillering and panicle initiation. Saturated conditions were achieved by frequent application of smaller quantities of water and under AWD water was applied to soil when hair line cracks were developing in soil. Leaf-area index (LAI) was measured with canopy analyser Accupar LP-80 (Decagon Devices, USA) and weed index for different weed-control treatments was worked out as:

$$\text{Weed-control efficiency ((WCE))} = \frac{(\text{WDC} - \text{WDT})}{\text{WDC}} \times 100$$

where, WCE, weed-control efficiency; WDC, weed dry weight in control plot; WDT, weed dry weight in treated plot.

$$\text{Weed index (WI)} = \frac{(Y_{WF} - Y_T)}{Y_{WF}} \times 100$$

where, Y_{WF} is the crop yield in weed free plot, and Y_T is the crop yield in treated plot.

The data were statistically analyzed for critical difference as per the standard methods.

RESULTS AND DISCUSSION

Growth attributes

The pooled data of 2012 and 2013 (Table 1) indicated that among the water regimes saturated water regime significantly recorded taller higher plant height, number of tillers/plant, dry-matter accumulation and leaf-area index (LAI) at 75 DAT and the average increase in tillers/plant, dry-matter accumulation and LAI at saturation over continuous flooding was 32.8, 8.6 and 7.1%, respectively. Higher plant height, tiller number/plant, dry matter and LAI in saturation water regime could be attributed to better environment and higher nutrient availability in saturation water regimes. Fonteh *et al.* (2013) reported similar results. Significant increase in plant height, tillers/plant, dry-matter accumulation and LAI were recorded by differ-

ent weed-management options as against weedy check (Table 1). Among the weed-management practices, sequential application of pyrazosulfuron-ethyl @ 20 g/ha+ cyhalofop-butyl @ 60 g/ha though at par with pyrazosulfuron-ethyl @ 20 g/ha, significantly increased the plant height, tillers/plant, dry-matter accumulation and LAI over weedy check and the other weed-control treatments. The average increase in plant height, tillers/plant, dry-matter accumulation and LAI by sequential application of pyrazosulfuron-ethyl @ 20 g/ha + cyhalofop-butyl @ 60 g/ha over weedy check were 3.4, 35.3, 40.3 and 50.2% respectively. The reduction in weed growth with the herbicidal application might have allowed the crop to enjoy adequate nutrient availability, resulting in better accumulation of photosynthates and thus increasing plant height, tillers/plant, dry-matter accumulation and LAI. The results are in close conformity with those of Walia *et al.* (2008) and Kumar (2012).

Yield-attributing characters

Pooled data (Table 1) indicates that among the water regimes, saturated significantly increased panicles/m², panicle length, and grains/panicle; however, the effect of water regimes was non-significant on panicle weight and 1,000-grain weight. The average superiority exhibited by saturated water regime in increasing the panicles/m², panicle length and grains/panicle over alternate wetting

and drying (AWD) was 4.4, 4.3 and 6.8% and over continuous flooding 6.8, 7.6 and 12.6%, respectively. This may be attributed to increased oxygen availability for better root growth and availability of nutrients which ensured better plant establishment and vigorous growth (Juraimi *et al.*, 2011) reported similar findings. Among the herbicidal treatments sequential application of pyrazosulfuron-ethyl @ 20 g/ha fb cyhalofop-butyl @ 60 g/ha significantly increased all the yield-attributing characters, viz. panicles/m², panicle length, panicle weight, grains/panicle and 1,000-grain weight over the other treatments. This could be ascribed to the fact in weed-free and sequential application of pyrazosulfuron-ethyl @ 20 g/ha fb cyhalofop-butyl @ 60 g/ha treated plots utilized the nutrients and other growth factors due to less competition between crop and weeds and hence all the yield-attributing characters acquired higher values. The results are in close conformity with those of Rajkhow *et al.* (2007) and Kumar (2012).

Grain and straw yield

There was a significant increase in the grain yield of rice under saturated water regime over flooded conditions; however, AWD was at par with saturation water regime (Table 2). The data further revealed that the straw yield and harvest index showed a significant improvement under saturated conditions over AWD and continuous flooding. This could be attributed to better performance of

Table 1. Effect of water regimes and weed-management practices on growth and yield attributes of rice under system of rice intensification (mean data of 2 years)

Treatment	Plant height (cm)	Tillers/plant	Dry-matter accumulation (t/ha)	Leaf-area index at flowering	Panicles/m ²	Panicle length (cm)	Panicle weight (g)	Grains/panicle	1,000-grain weight (g)
<i>Water regimes</i>									
AWD	118.68	27.09	16.38	5.12	385.4	22.8	2.8	98.2	23.8
SC	121.36	31.93	17.14	5.34	403.3	23.8	2.9	105.4	23.8
FL	119.79	21.52	15.64	4.95	375.7	22.0	2.6	92.1	23.6
SEm±	1.77	0.87	0.06	0.06	3.52	0.20	0.05	1.83	0.09
CD (P = 0.05)	NS	3.39	0.24	0.21	14.25	0.80	NS	7.00	NS
<i>Weed-management options (WMO)</i>									
W ₁	118.0	24.53	15.91	4.97	375.6	22.6	2.7	92.7	23.0
W ₂	120.3	29.95	17.70	5.68	418.5	23.4	2.9	105.9	25.0
W ₃	117.7	22.01	14.51	4.72	348.5	22.1	2.6	91.4	22.8
W ₄	121.1	31.06	18.35	6.11	453.8	24.6	3.1	111.7	25.2
W ₅	119.7	28.02	16.17	5.16	392.7	22.9	2.8	94.6	24.2
W ₆	125.7	33.20	21.11	6.26	460.5	24.9	3.2	118.9	25.4
W ₇	116.9	20.08	10.95	3.04	260.3	19.4	2.1	74.7	21.6
SEm±	1.10	1.20	0.25	0.13	9.58	0.47	0.07	2.34	0.17
CD (P=0.05)	3.14	3.42	0.72	0.36	27.45	1.36	0.19	6.84	0.49

AWD, Alternative wetting and drying; SC, saturated conditions; FL, continuous flooding; W₁, pyrazosulfuron ethyl 20 g/ha at 3 DAT; W₂, cyhalofop-butyl 80 g/ha at 15 DAT; W₃, pyrazosulfuron ethyl 20 g/ha fb cyhalofop butyl 80 g/ha at 3 and 15 DAT; W₄, butachlor 1.5 kg/ha at 3 DAT; W₅, cono-weeding at 15, 25 and 35 DAT; W₆, weedy check; W₇, weed free

yield-contributing characters due to lower competition, and through optimum utilization of all inputs under saturated conditions over AWD and continuous flooding water regimes. These results are in conformity with Rajkhowa *et al.* (2007) and Son *et al.* (2008). The data regarding weed-management options revealed that among different herbicidal treatments sequential application of pyrazosulfuron-ethyl @ 20 g/ha fb cyhalofop-butyl @ 60 g/ha significantly increased grain yield, straw yield and harvest index of rice over the other weed-control measures (Table 2). Mean grain yield and straw yield also followed similar trend. Higher grain yield with sequential application of pyrazosulfuron-ethyl @ 20 g/ha fb cyhalofop-butyl @ 60 g/ha application could be attributed due to significant improvement in all yield attributes and reduction in crop-weed competition. Pyrazosulfuron-ethyl is a broad-spectrum pre-emergence herbicide whereas, cyhalofop-butyl is a post-emergence herbicide effective against the grasses. Their sequential application resulted in overall better weed control and therefore the final yield. These results confirm the findings of Kumar (2012) and Ganai *et al.* (2014).

Weed density, weed dry weight and weed control efficiency

The study revealed that weed density and weed dry weights (Table 3) were significantly lower in flooding water regime than in saturation and alternate wetting and drying (AWD) during all crop growth stages. The lower

density and dry matter of weeds in flooded water regime at 30, 60 and 90 DAT may be due to frequent killing of weeds by continuous submergence. However, under AWD water regime higher dry weight of weeds may be attributed due to luxurious and continuous germination of weeds and keen competition between crop and weeds for growth factor. The data with regard to weed-control efficiency (Table 3) revealed that flooded conditions proved efficient in controlling weeds during all crop-growth stages as compared to saturation and AWD water regimes. The lower dry matter of weeds recorded under flooding could have increased efficiency of the treatment in controlling the weeds. Juraimi *et al.* (2011) reported similar results. All the weed-control treatments significantly reduced the weed densities and weed dry weight as compared to weedy check (Table 3). Among the weed-control options, apart from weed-free check, sequential application of pyrazosulfuron-ethyl @ 20 g/ha fb cyhalofop-butyl @ 60 g/ha though at par with application of pyrazosulfuron-ethyl @ 20 g/ha significantly reduced weed density and dry-matter of weeds compared with the other weed control treatments. The combination of flooded water regime and sequential application of pyrazosulfuron-ethyl @ 20 g/ha + cyhalofop-butyl @ 60 g/ha though at par with pyrazosulfuron-ethyl @ 20 g/ha recorded significant result in the maximum reduction in weed densities and weed dry matter at 60 DAT during both the years (Table 3). This may be due to the fact that herbicides not only exhibited significantly lesser toxicity to rice seedling but

Table 2. Effect of water regimes and weed-management options on yield and economics of rice (mean data of 2 years)

Treatment	Grain yield (t/ha)		Mean	Straw yield (t/ha)		Mean	Harvest index (%)	Cost of cultivation ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Benefit: cost ratio
	2012	2013		2012	2013					
AWD	7.53	7.69	7.61	9.41	9.55	9.48	44.20	39.82	88.14	2.06
SC	7.81	7.98	7.90	9.63	9.77	9.70	44.50	44.18	90.58	2.07
FL	7.35	7.51	7.43	9.32	9.40	9.36	43.95	45.18	84.00	1.87
SEm±	0.052	0.054	0.053	0.05	0.08	0.07	0.11	-	-	-
CD (P=0.05)	0.20	0.21	0.21	0.20	0.21	0.21	0.40	-	-	-
<i>Weed-management options (WMO)</i>										
W ₁	7.49	7.67	7.58	9.43	9.58	9.51	44.40	49.82	81.15	1.63
W ₂	8.36	8.56	8.46	10.08	10.23	10.16	45.40	41.32	100.16	2.43
W ₃	7.16	7.33	7.25	9.55	9.58	9.57	43.10	41.22	85.71	2.09
W ₄	8.54	8.74	8.64	9.90	10.05	9.98	46.40	41.72	101.99	2.45
W ₅	7.74	7.93	7.84	9.37	9.50	9.44	45.25	41.54	92.48	2.23
W ₆	8.92	9.03	8.97	9.89	10.03	9.96	47.50	52.82	94.84	1.80
W ₇	4.73	4.85	4.79	7.95	8.04	8.00	37.45	40.82	56.67	1.39
SEm±	0.05	0.05	0.05	0.09	0.10	0.10	0.29	-	-	-
CD (P=0.05)	0.14	0.15	0.15	0.26	0.29	0.28	0.84	-	-	-

AWD, Alternative wetting and drying; SC, saturated conditions; FL, continuous flooding; W₁, pyrazosulfuron ethyl 20 g/ha at 3 DAT; W₂, cyhalofop-butyl 80 g/ha at 15 DAT; W₃, pyrazosulfuron ethyl 20 g/ha fb cyhalofop butyl 80 g/ha at 3 and 15 DAT; W₄, butachlor 1.5 kg/ha at 3DAT; W₅, cono-weeding at 15, 25 and 35 DAT; W₆, weedy check; W₇, weed free

Table 3. Weed density, weed dry-matter, weeds control efficiency and weed index in rice as affected by water regimes and weed management options (mean data of 2 years)

Treatment	Weed density (no./m ²)		Weed drymatter (g/m ²)		Weed control efficiency (%) 60 DAT	Weed index (%)
	30 DAT	60 DAT	30 DAT	60 DAT		
Water regimes (WR)						
AWD	3.17 (10.09)	4.89 (30.54)	4.78 (26.36)	4.49 (24.20)	59.30	3.61 (15.27)
SC	2.94 (9.10)	4.55 (26.25)	4.46 (23.83)	4.20 (20.88)	60.22	3.63 (15.42)
FL	2.79 (8.00)	4.29 (23.21)	4.22 (21.16)	3.94 (18.62)	62.22	3.42 (13.78)
SEm±	0.05	0.05	0.03	0.05	-	0.085
CD (P=0.05)	0.21	0.18	0.13	0.19	-	NS
Weed-management options (WMO)						
W ₁	3.54 (11.64)	5.93 (34.31)	5.56 (30.05)	5.21 (26.30)	54.3	4.06 (15.48)
W ₂	2.07 (3.46)	2.21 (3.91)	2.06 (4.76)	2.62 (5.88)	89.8	2.69 (11.47)
W ₃	3.89 (14.25)	6.35 (39.66)	5.95 (34.67)	5.53 (29.72)	49.5	4.49 (19.21)
W ₄	1.96 (2.87)	2.09 (3.40)	1.83 (3.29)	2.51 (5.30)	90.9	2.08 (3.63)
W ₅	3.62 (12.21)	6.20 (37.74)	5.81 (33.07)	4.96 (23.69)	61.6	3.67 (12.61)
W ₆	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	100	1.00 (0.00)
W ₇	4.70 (21.25)	8.25 (67.66)	7.69 (58.34)	7.65 (57.73)	-	6.93 (47.12)
SEm±	0.09	0.10	0.09	0.07	-	0.085
CD (P=0.05)	0.26	0.28	0.25	0.21	-	0.23
WR × WMP	NS	0.50	NS	0.55	-	NS

Figures in parentheses are original values, data subjected to $\sqrt{x+1}$ transformation

AWD, Alternative wetting and drying; SC, saturated conditions; FL, continuous flooding; W₁, pyrazosulfuron ethyl 20 g/ha at 3 DAT; W₂, cyhalofop-butyl 80 g/ha at 15 DAT; W₃, pyrazosulfuron ethyl 20 g/ha fb cyhalofop butyl 80 g/ha at 3 and 15 DAT; W₄, butachlor 1.5 kg/ha at 3DAT; W₅, cono-weeding at 15, 25 and 35 DAT; W₆, weedy check; W₇, weed free; DAT, days after transplanting

controlled the weeds very efficiently. Higher weed control efficiency was recorded in sequential application of pyrazosulfuron-ethyl @ 20 g/ha fb cyhalofop-butyl @ 60 g/ha. This could be attributed due to reduction of weed biomass on account of effective weed-control measures adopted and thus resulted in higher weed-control efficiency. Application of pyrazosulfuron-ethyl @ 20 g/ha fb cyhalofop-butyl provided owing to their pre-emergence and post-emergence nature, respectively, provided a broad-spectrum control of both broad-leaf and grassy weeds. This resulted in an enhanced efficiency when applied in a sequence. The results are in close conformity with those of Kiran *et al.* (2010) and Ganai *et al.* (2014). Significantly lower weed index was recorded by sequential application of pyrazosulfuron-ethyl @ 20 g/ha + cyhalofop-butyl @ 60 g/ha followed by alone application of pyrazosulfuron-ethyl @ 20 g/ha and higher weed index was recorded with cyhalofop-butyl. This could be attributed to the fact that owing to better weed control higher yield was recorded with sequential application of pyrazosulfuron-ethyl @ 20 g/ha fb cyhalofop-butyl @ 60 g/ha. The results are in close conformity with those of Kiran *et al.* (2010).

Relative economics

The highest benefit: cost (B:C) ratio was achieved with saturation water regime (2.07) and the sequential application of pyrazosulfuron-ethyl @ 20 g/ha fb cyhalofop-butyl @ 60 g/ha (2.45) and the highest mean net returns were achieved by saturation water regime (₹90.58 × 10³/ha) and sequential application of pyrazosulfuron-ethyl @ 20 g/ha fb cyhalofop-butyl @ 60 g/ha (₹101.99 × 10³/ha) followed by application of pyrazosulfuron-ethyl @ 20 g (₹100.16 × 10³/ha). The results are in line with that of Ganai *et al.* (2014).

It was concluded that saturated water regime with sequential application of pyrazosulfuron-ethyl @ 20 g/ha fb cyhalofop-butyl @ 60 g/ha may be recommended for effective and economical weed control in rice under system of rice intensification for temperate Kashmir Valley.

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