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EFFECT OF WATER REGIMES AND WEED MANAGEMENT PRACTICES ON NUTRIENT UPTAKE BY RICE AND WEEDS UNDER THE SYSTEM OF RICE INTENSIFICATION

Manzoor A. Ganai, M. Anwar Bhat, A. Hussian, Tauseef Ahmad, N.A. Telli and Talib Hussian

Mountain Research Centre for Field Crops, S.K. University of Agricultural Sciences and Technology of Kashmir, Khudwani, Anantnag - 192 102, Jammu & Kashmir (*India*)
*e-mail: *ganai95@gmail.com*

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ABSTRACT

A field experiment was conducted in *kharif* 2012 and 2013 at MRCFC, SKUAST, Khudwani (Kashmir) on a silty clay loam soil to evaluate the impact of water regimes and weed management practices on nutrient uptake in rice and weeds under SRI. The soil at experimental site was neutral in reaction, medium in available P, K and organic carbon and low in available N. The treatments comprised of 3 irrigations schedules [alternate wetting and drying (AWD), continuous saturated condition and continuous flooding] and 7 weed management practices *viz*., 4 herbicidal treatments [pyrazosulfuron ethyl @ 20 g *a.i.* ha^{-1} (3 DAT); cyhalofop butyl @ 80 g *a.i.* ha^{-1} (15 DAT); pyrazosulfuron ethyl 20 g *a.i.* followed by cyhalofop butyl 80 g *a.i.* ha^{-1} (3 and 15 DAT), and butachlor @ 1.5 kg *a.i.* ha^{-1} (3 DAT)]; cono weeding, weedy check and weed-free control. The results revealed that saturated water regime treatment had highest uptake of macronutrients by grain and straw, while highest uptake of macro-nutrients by weeds was in AWD and lowest in continuous flooding. Among weed control measures, the lowest macronutrients uptake by crop was associated with post-emergence application of cyhalofop-butyl and highest amount of NPK depletion by weeds was observed in unweeded control. Minimum NPK uptake by weeds was noticed in sequential application of pyrazosulfuron-ethyl @ 20 g *a.i.* ha^{-1} and cyhalofop-butyl @ 60 g *a.i.* ha^{-1} treatment.

Key words: SRI, water regimes, nutrient up-take, rice, weeds

INTRODUCTION

Rice (*Oryza sativa* L.) is a premier food crop of India, and the national food security system in the country largely depends on rice productivity under different ecosystems. Among the rice growing countries, India stands 1st in area (36.95 million ha) and 2nd in production (120.6 million t) next to China (FAO STAT, 2010). However, the average rice productivity in India is only 3.26 t ha^{-1} against the global average of 4.37 t ha^{-1} (FAO STAT, 2010). In Jammu & Kashmir, rice is cultivated on an area of 0.274 million ha with production of around 0.9 million t and productivity of 3.24 t ha^{-1} (Economic Survey, 2013-14).

The existing system of paddy production, particularly green revolution technology, is input intensive and favours cash rich farmers. Unfortunately, increasing prices of agricultural inputs prevent poor farmers from completely adopting modern production technologies (Stoop *et al*., 2002). 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) was recently promoted as an alternative technology and resource management strategy for rice cultivation that may offer opportunities to boost rice yields with less external inputs (Uphoff and Randriamiharisoa, 2002). An additional benefit from cultivating rice in un-flooded paddies, as done with SRI during most of the growing season, would be some reduction in greenhouse gas emissions (Roger and Ladha, 1992). 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 as well as controls weeds, water management in such a way that there is no continuously standing water during vegetative growth phase and reliance on compost as far as possible with less thrust on chemical fertilizer use. Nevertheless, when rice fields are not flooded continuously and plants are widely spaced as recommended under SRI, weeds get a better chance to grow; so efficient weed management practices are required. The higher amount of labour for weeding is one of the most criticized aspects of SRI. Hence, efforts must be made to eliminate weeds and minimize their competition with rice plants by using less labour for effective weed control methods. Weed control helps to enhance production environment, thereby allows more of the inherent capacity of plant to express itself in higher yields than otherwise would not occur. Therefore, it is essential to control weeds in rice fields for greater utilization of growth factors by the crop to get higher yield. When fields are not kept continuously flooded, weed growth becomes a challenge and farmers tend to use excess water to check weed growth and to reduce labour requirements for weed control. Weeding is a 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. They are often the best alternatives to control weeds in least amount of time and labour.

Kashmir valley with temperate climate has a unique set of varieties suited to its agro-climatic situation. But the average yields (3.23 t ha^{-1}) are far below the potential yields (9 t ha^{-1}) owing to several constraints, the main among them being weed infestation, poor water management and poor adoption of new technologies. Therefore, cost effective and consistent weed management system and appropriate irrigation water management needs to be identified for SRI. Therefore, a field study was conducted to find the most suitable water regime and weed management practice for SRI cultivation under Kashmir conditions.

MATERIALS AND METHODS

A field experiment was conducted at MRCFC, SKUAST, Khudwani (Kashmir) which is located at 33°43'15'' N, 75°5'39''E and 1,596 m amsl. The site falls in mid-altitude temperate zone characterized by hot summers and very cold winters with average annual precipitation of 812 mm. The experiment was conducted in *kharif* 2012 and 2013 on a silty clay loam soil, neutral in pH (6.78), low in available N (215 kg ha^{-1}) and medium in available P (15.0 kg ha^{-1}) and K (205 kg ha^{-1}). The rainfall received during crop-growing seasons [May to October] of 2012 and 2013 was 32 and 60 mm, respectively. The experiment comprised of 3 water regimes {alternate wetting and drying (AWD), continuous saturated and continuous flooding} and 7 weed control methods {cono weedings at 15, 25 and 35 DAT; pyrazosulfuron ethyl @ 20 g *a.i.* ha^{-1} (3 DAT); cyhalofop butyl @ 80 g *a.i.* ha^{-1} (15 DAT); pyrazosulfuron ethyl 20 g *a.i.* followed by (fb) cyhalofop butyl 80 g *a.i.* ha^{-1} (3 and 15 DAT); butachlor @ 1.5 kg *a.i.* ha^{-1} (3 DAT); weed-free and weedy check (control)}. The experiment was laid out in a split plot design with three replications for each treatment. On the day of transplanting there was no standing water in field. Transplantation of rice cv. 'Jehlum' was carried out in the 1st week of June and one seedling of 14 days old per hill was transplanted at plant spacing of 25 x 25 cm. Marked ropes at equal distances were used to achieve square planting. All the plots received uniform dose of 120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 30 kg K_2O ha^{-1}. Whole P, K and half N were applied as basal dose before transplantation. The remaining half N was applied in two equal splits at tillering and panicle initiation stages; however, farm yard manure (FYM) @ 10 t ha^{-1} was incorporated 15 days prior to experimentation. Crop was irrigated as per treatments and irrigation was applied in early morning. Saturated condition was 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. After recording dry weight of plant samples, collected from each plot, the oven dried samples were ground in Wileys mill and passed through 32 mesh sieve, both of rice and weeds were grounded and subsequently used for chemical analysis. The data was statistically analyzed for critical difference as per the standard methods (Cohran and Cox, 1955).

RESULTS AND DISCUSSION

Grain and straw yield and weed dry matter

There was a significant increase in rice grain yield under saturated water regime over flooding water regime; however, AWD was at par with saturation water regime (Table 1). The straw yield showed significant improvement under saturation conditions over AWD and continuous flooding. This could be attributed to better performance of yield contributing characters due to lower competition and through optimum utilization of all inputs under saturation water regime over AWD and continuous flooding water regimes. These results are in conformity with Rajkhowa *et al.* (2007) and Son *et al.* (2008). Among the different weed control measures, apart from weed free treatment, sequential application of pyrazosulfuron-ethyl @ 20 g *a.i.* ha^{-1} fb cyhalofop-butyl @ 60 g *a.i.* ha^{-1} significantly increased grain and straw yield of rice over other weed control measures. Higher grain yield with sequential application of pyrazosulfuron-ethyl @ 20 g *a.i.* ha^{-1} fb cyhalofop-butyl @ 60 g *a.i.* ha^{-1} application could be attributed due to the significant improvement in all yield attributes and reduction in crop-weed competition. The results are in close conformity with Kumar (2012) and Ganai *et al.*

Table 1: Effect of water regimes and weed management practices on rice grain and straw yield and weed dry matter under SRI (Average of two years)

Treatments	Rice grain yield (q ha^{-1})	Rice straw yield (q ha^{-1})	Weed dry matter at harvest (kg ha^{-1})
<u>Water regimes</u>			
AWD	9.41	9.52	5.42 (36.21)
Saturated	9.63	9.74	5.19 (33.10)
Flooding	9.32	9.38	4.95 (30.27)
SEm ±	0.05	0.08	0.06
$CD_{0.05}$	0.2	0.21	0.21
<u>Weed management practices</u>			
Cono weeding (3 times)	9.43	9.55	6.46 (41.25)
Pyrazosulfuron – ethyl	10.08	10.20	3.70 (9.52)
Cyhalofop butyl	9.55	9.58	6.88 (46.42)
Pyrazosulfuron fb Cyhalofop	9.90	10.02	3.04 (8.35)
Butachlor	9.37	9.47	6.19 (37.53)
Weed free	9.89	10.00	1.00 (0.00)
Weedy check	7.95	9.02	9.50 (89.50)
SEm ±	0.09	0.10	0.09
$CD_{0.05}$	0.26	0.29	0.24

Figures in parenthesis are original values, data subjected to $\sqrt{x+1}$ transformation; AWD = Alternate wetting and drying

(2014). The present study also revealed that weed dry weight was significantly lower in flooding water regime than in saturation and alternate wetting and drying (AWD) at harvest (Table 1). The lower dry matter of weeds in flooding water regime at harvest 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. All the weed control treatment significantly reduced weed dry weight as compared to weedy check. Among weed control measures, apart from weed free check, sequential application of pyrazosulfuron-ethyl @ 20 g *a.i.* ha^{-1} fb cyhalofop-butyl @ 60 g *a.i.* ha^{-1} though at par with application of pyrazosulfuron-ethyl @ 20 g *a.i.* ha^{-1} significantly reduced dry matter of weeds over other weed control treatments. The results are in close conformity with those of Kiran *et al.* (2010) and Ganai *et al.* (2014).

Nutrient concentration and uptake by rice grain and straw

The pooled data on NPK concentrations in rice grain and straw revealed that saturated regime significantly had higher NPK concentration in grain and straw over AWD and continuous flooding (Table 2). AWD water regime, in turn, recorded significantly higher nutrient concentrations in grain and straw over flooding. However in AWD, P content in straw was at par with continuous flooding regime in both the years. The results are in line with Stoop *et al.* (2002). Among weed management practices, weed free treatment showed significantly higher NPK content in grain and straw over weedy check in both the years. Among herbicidal treatments, sequential application of pyrazo-sulfuron-ethyl @ 20 g *a.i.* ha^{-1} fb cyhalofop-butyl @ 60 g *a.i.* ha^{-1} produced highest content of NPK in both grain and straw in both the years. The results are in line with Kumar (2012).

Nutrient uptake by crop

Saturated regime recorded the highest uptake of macronutrients (Table 2) by grain and straw. This could be due to the fact that yield contributing factors were significantly superior in saturated regime than in other water regimes which resulted in higher biomass accumulation of rice thus have higher nutrient uptake. Higher biomass with potential advantages for nutrient uptake by rice was also recorded by Stoop *et al.* (2002). Meanwhile, it was found that N, P and K uptake by grain and straw of rice was significantly influenced by weed control measures. The weed free condition resulted

Table 2: Effect of water regimes and weed management practices on nutrient status by rice grain and straw under SRI (Average of two years data)

Treatments	NPK concentration (%)						NPK uptake (kg ha^{-1})					
	Grain			Straw			Grain			Straw		
	N	P	K	N	P	K	N	P	K	N	P	K
Water regimes												
AWD	1.03	0.234	0.250	0.501	0.072	1.583	78.7	17.92	19.08	47.6	6.79	151.4
Saturated	1.09	0.236	0.259	0.522	0.073	1.669	86.0	18.70	20.54	50.8	7.05	162.2
Flooding	0.99	0.233	0.228	0.484	0.070	1.560	73.5	17.42	17.05	45.4	6.49	148.4
SEm ±	0.002	0.000	0.001	0.002	0.000	0.001	0.68	0.15	0.15	0.31	0.055	1.02
$CD_{0.05}$	0.01	0.001	0.003	0.006	0.001	0.003	2.62	0.56	0.57	1.19	0.21	3.97
Weed management practices												
Cono weeding (3 times)	1.03	0.237	0.248	0.499	0.070	1.613	78.1	17.94	18.78	47.5	6.65	153.3
Pyrazosulfuron-ethyl	1.05	0.230	0.236	0.498	0.070	1.619	89.0	19.00	19.94	50.5	7.10	164.5
Cyhalofop butyl	1.02	0.229	0.236	0.480	0.069	1.571	74.0	16.58	17.08	45.9	6.59	150.4
Pyrazosulfuron fb cyhalofop	1.06	0.248	0.255	0.525	0.074	1.665	91.6	21.37	22.01	52.3	7.34	166.1
Butachlor	1.04	0.243	0.255	0.511	0.073	1.650	81.8	19.02	19.96	48.2	6.85	155.8
Weed free	1.07	0.248	0.264	0.541	0.075	1.672	95.8	22.24	23.73	53.9	7.44	166.7
Weedy check	0.96	0.210	0.227	0.464	0.069	1.473	45.5	9.97	10.74	37.1	5.47	117.9
SEm ±	0.002	0.001	0.001	0.003	0.001	0.002	0.63	0.16	0.16	0.51	0.09	1.56
$CD_{0.05}$	0.01	0.002	0.003	0.005	0.002	0.005	1.80	0.46	0.47	1.50	0.26	4.47

AWD = Alternate wetting and drying

resulted in high uptake of macronutrients at harvest over other treatments, except combined application of pyrazosulfuron-ethyl and cyhalofop-butyl, closely followed by application of pyrazosulfuron-ethyl alone. This might be due to increased dry matter accumulation by crop under poor weed competition. Amongst weed control measures, the lowest uptake of macronutrients by crop was associated with post-emergence application of cyhalofop-butyl. This is due to the fact that field was infected with complex weed flora against which the selective herbicide failed to register a good killing activity and lower residual effect of herbicide with the passage of time. The results corroborate with those of Kathiresan and Veerabadran (1991) and Kumar (2012).

NPK concentration in weeds

The data presented in Table 3 depict the effect of water regimes on NPK concentration in weeds. The weeds under AWD regime possessed higher nutrient NPK concentrations, as compared to saturated and flooding regime. Among the weed management practices, weedy check significantly increased the NPK concentration in weeds over other weed control methods during both the years. However, all weed control treatments were at par with each other with respect to NPK concentrations during both the years. The results are supported by the findings of Stoop *et al.* (2002) and Salim and Shezad (2008).

Table 3: Effect of water regimes and weed management practices on nutrient status in weeds under SRI (mean of two years data)

Treatments	NPK concentration (%)			NPK uptake (kg ha^{-1})		
	N	P	K	N	P	K
Water regimes						
AWD	1.49 (1.26)	1.06 (0.118)	1.54 (1.43)	2.87 (8.25)	1.322 (0.791)	3.03 (9.33)
Saturated	1.48 (1.24)	1.06 (0.117)	1.54 (1.41)	2.74 (7.39)	1.294 (0.712)	2.89 (8.38)
Flooding	1.47 (1.20)	1.05 (0.115)	1.53 (1.38)	2.61 (6.65)	1.270 (0.646)	2.76 (7.59)
SEm ±	0.003	0.0002	0.002	0.03	0.005	0.03
$CD_{0.05}$	0.01	0.001	0.004	0.11	0.04	0.11
Weed management practices						
Cono weeding (3 times)	1.56 (1.43)	1.07 (0.139)	1.63 (1.65)	3.07 (8.42)	1.348 (0.818)	3.27 (9.68)
Pyrazosulfuron – ethyl	1.55 (1.40)	1.06 (0.128)	1.61 (1.60)	1.91 (2.64)	1.114 (0.241)	2.00 (3.00)
Cyhalofop – butyl	1.57 (1.47)	1.07 (0.142)	1.63 (1.67)	3.20 (9.23)	1.376 (0.897)	3.38 (10.44)
Pyrazosulfuron fb Cyhalofop	1.54 (1.38)	1.06 (0.125)	1.61 (1.58)	1.82 (2.33)	1.100 (0.210)	1.91 (2.66)
Butachlor	1.56 (1.42)	1.07 (0.134)	1.62 (1.62)	2.94 (7.63)	1.311 (0.719)	3.12 (8.73)
Weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Weedy check	1.59 (1.51)	1.08 (0.151)	1.64 (1.70)	4.38 (18.15)	1.676 (1.811)	4.63 (20.41)
SEm ±	0.003	0.0003	0.002	0.02	0.006	0.03
$CD_{0.05}$	0.10	0.001	0.004	0.07	0.016	0.07

Figures in parenthesis are original values, data subjected to $\sqrt{x+1}$ transformation; AWD = Alternate wetting and drying

Nutrient uptake by weeds

Among water regimes, the highest uptake of macronutrients by weeds was observed in AWD and lowest in continuous flooding (Table 3). The weed density and dry weight were higher in AWD water regime and reduction in weed densities and their dry weight in continuous flooding regimes. The results are supported by Stoop *et al.* (2002) and Salim and Shezad (2008).

The highest amount of nitrogen, phosphorus and potassium depletion by weeds was recorded in weedy check (control) plots. This is obvious because both density and dry matter production were relatively higher in this treatment as compared to weed control treatments. Among weed control treatments, the differences observed in nutrient removal by weeds could be explained on the basis of their differential effect on population and growth of weeds. Minimum N, P and K uptake by weeds was recorded in plots with sequential application of pyrazosulfuron-ethyl @ 20 g *a.i.* ha^{-1} fb cyhalofop-butyl @ 60 g *a.i.* ha^{-1} closely followed by application of pyrazosulfuron-ethyl @ 20 g *a.i.* ha^{-1} alone. This could be due to lower weed populations and biomass production by the weeds

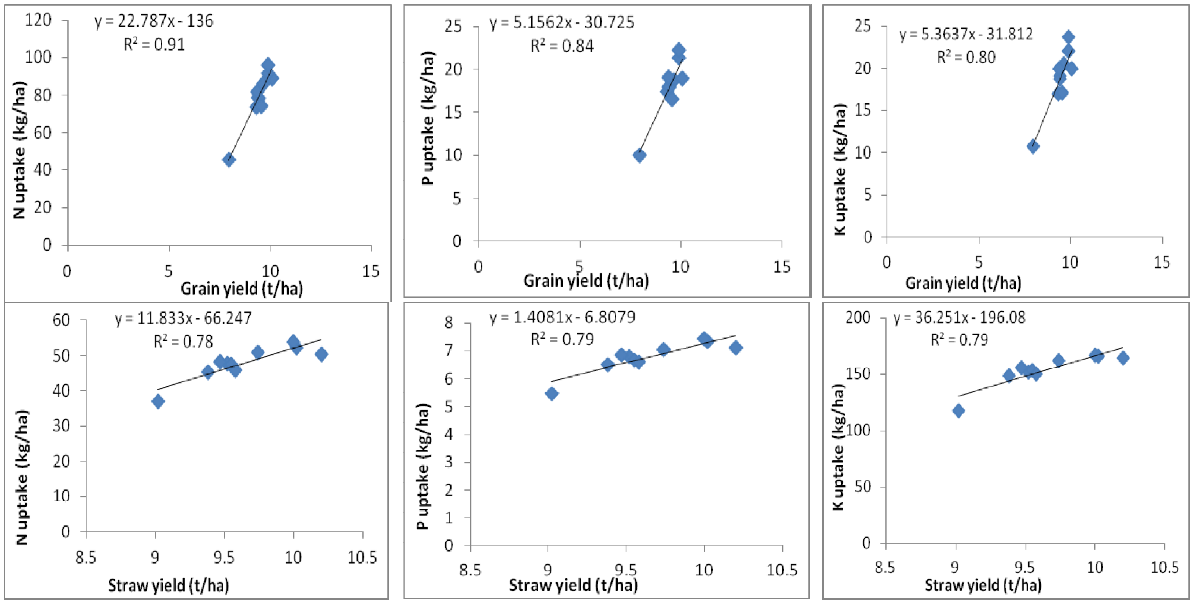

Fig. 1: Relationship between grain and straw yield of rice with NPK uptake under SRI

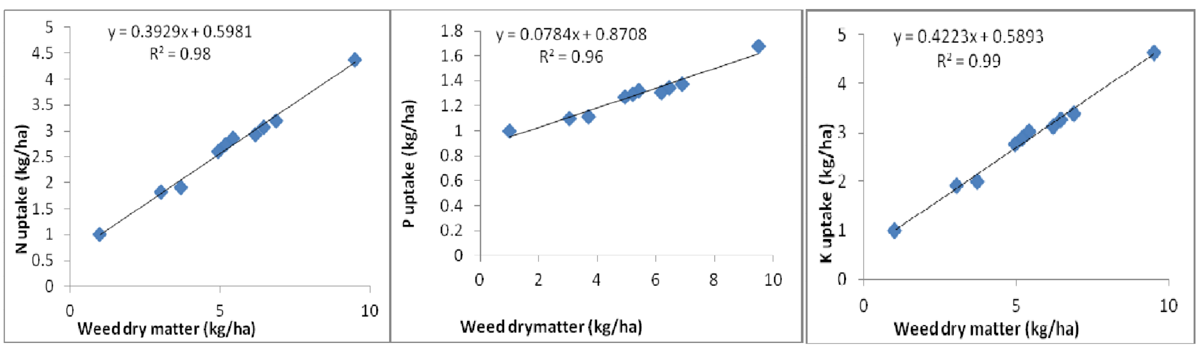

Fig. 2: Relationship between the weed dry matter with NPK uptake by weeds under SRI

under continuous influence of these weed control treatments. The results are in agreement with Angiras and Sharma (1998), Singh *et al.* (2004) and Kumar (2012).

Regression and correlation studies

The grain and straw yield and weed dry matter exhibited highly significant correlation with N, P and K uptake (Fig. 1 & 2). The R^2 for grain yield with N, P and K were 0.91, 0.84 and 0.80 and for straw yield with N, P and K were 0.78, 0.79 and 0.79, respectively. The R^2 values for weed dry matter with N (0.99), P (0.96) and K (0.99) were also highly significant. The variations in N, P and K for grain and straw yield could be explained to the extent of 91, 84, 80, 78, 79 and 79%, respectively, and for weed dry matter with N, P and K could be explained to tune of 99, 96 and 99%, respectively. The results are in line with those of Ganai *et al.* (2014).

Conclusions: From the present study it may be concluded that saturated regime gave highest macro-nutrients uptake by grain and straw, while highest macronutrient uptake by weeds was in AWD and lowest in continuous flooding. Among weed control measures, the lowest macronutrient uptake by crop was realized with post-emergence application of cyhalofop-butyl and highest amount of N, P and K depletion by weeds was in control (weedy check) treatment. Moreover, minimum N, P and K uptake by weeds was observed in treatment of sequential application of pyrazosulfuron-ethyl @ 20 g *a.i.* ha^{-1} fb cyhalofop-butyl @ 60 g *a.i.* ha^{-1}.

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