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Effect of tillage, water regimes and weed management methods on weeds and transplanted rice

B. Renjan* and Sansamma George

College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram, Kerala 695 522

**Email: renjan.b@kau.in*

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ABSTRACT

Field experiments were conducted during 2016 rainy and winter seasons to study the effect of tillage, water regimes and weed management methods on weeds and transplanted rice. The design was split plot with combinations of tillage and water regimes as main plot treatments and weed management methods as subplot treatments. The weed biomass was significantly reduced and the rice performance was superior under intensive tillage (three ploughings followed by (*fb*) puddling), when compared to the conventional farmers' practice of land preparation. Among the water regimes, continuous deep water ponding (> 7.5 cm water) either till panicle initiation or grain filling stage suppressed weed growth better than that under the recommended practice of maintaining about 5 cm water level with intermittent drainage. Weed control efficiency (WCE) was maximum under azimsulfuron 35 g/ha applied at 15 days after transplanting (DAT), followed by pre-plant application of oxyflourfen *fb* one hand weeding at 20 DAT.

INTRODUCTION

The attainment of optimal crop productivity in rice is hindered by several factors, of which weeds are recognized as the major biological constraint. The yield loss caused by weeds resulted from their competition for growth factors, *viz.* nutrients, soil moisture, light, space, *etc.* (Walia 2006, Rao and Nagamani 2010). In order to achieve higher benefits from applied inputs, weeds must be kept below economic threshold level through strategic management practices. Good land preparation, effective water management and use of herbicides are often considered as cost-effective alternatives to manual weeding. Subramanyam *et al.* (2007) reported that intensive puddling with continuous submergence could effectively reduce weed biomass in rice. Varughese (1996) observed that germination of grassy weeds could be effectively prevented by field submergence. According to De Datta (1981) herbicides are the most practical, effective and economical means of weed management in rice. The present study was therefore taken up to evaluate the effect of tillage, water regimes and weed control methods on weeds and crop performance in transplanted rice.

MATERIALS AND METHODS

The field experiment was conducted at the State seed farm, Kottarakkara, Kollam district, Kerala during rainy and winter seasons of 2016. The selected wetlands experienced humid tropical climate and there was a predominance of grassy weeds in the field (**Table 1**). The soil was sandy clay loam in texture with acidic pH (4.52). It was high in organic carbon (1.69%), available N (303.34 kg/ha), available P (13.52 kg/ha) and available K (153.42 kg/ha). The experiment was laid out in split plot design with 3 replications. Combinations of tillage and water regimes were the main plot treatments and weed management methods were taken as the sub-plot treatments. The tillage treatments included were: intensive tillage (three ploughings *fb* puddling) and farmers' practice (two ploughings *fb* puddling). The water regimes were: continuous deep water ponding *i.e.* > 7.5 cm from 7 days after transplanting (DAT) till grain filling stage, deep water ponding *i.e.* >7.5 cm from 7 DAT to panicle initiation and saturation thereafter and maintaining about 5 cm water level with intermittent drainage (KAU 2011). The weed management practices in the subplot treatments were: oxyflourfen 0.15 kg/ha *fb* HW at 20 DAT, azimsulfuron 35 g/ha, bispyribac sodium + metamifop

70 g/ha, fenoxaprop-*p*-ethyl 60 g/ha, hand weeding twice at 20 and 40 DAT and un-weeded control.

The winter crop was taken immediately after the harvest of rainy season crop without disturbing the field layout. The water regimes as per the treatments were maintained by providing 50 cm bunds to avoid seepage between plots. As the experimental site was part of a large block of paddy field, away from natural streams and main canals, the water regime was assumed to be influenced only by the treatments. Among the herbicides, oxyflorfen was applied as pre-plant, three days before transplanting and the other herbicides were given as post-emergence spray at 15 DAT. The composition of the weed spectra in the experimental site was observed initially from composite weed samples collected using quadrats (0.5 x 0.5 m) and the relative density (RD) were computed using the equations developed by Philips (1969). The weed samples from the crop were collected at 15, 30, 45 and 60 DAT and crop growth and yield attributes were taken at harvest. Application of manures and fertilizers as well as the other management practices were done as per the Package of practices (POP) recommendation of KAU (2011).

RESULTS AND DISCUSSION

Effect on weeds

The weed spectra in the experimental field comprised of two grass species, three sedges and eight broad leaved weeds and it was observed that there was a clear predominance of blood grass (*Isachne miliacea* Roth ex Roem. et Schult) in the field (**Table 1**). The weed biomass and WCE data revealed that during both seasons and all stages of observations, intensive tillage involving three ploughings suppressed rice weeds more efficiently than the conventional farmers' practice of land preparation (**Table 2** and **3**), confirming previous reports (Chauhan *et al*. 2014). Arguably, under intensive tillage the weed propagules in soil seed bank which germinated after the initial tillage operations were destroyed during the third round of ploughing and those seedlings which emerged later from deeper layers were less vigorous for establishment.

Rice tolerates low oxygen (hypoxic) conditions better than most weeds and thus flooding has traditionally been used as an effective method for control of many weed species. Hence in the present study also significant influence, of water depth on the weed control efficiency of the management practice, was observed. Irrespective of the seasons, the weed biomass and WCE recorded under deep water ponding were significantly lower than that under the recommended practice of maintaining approximately 5 cm water level with intermittent drainage. Between the two higher water regimes, water impounding till maturity registered comparatively lower weed biomass even though the variation fell short of statistical significance in some of the observations. Juraimi *et al*. (2009) observed that submergence of rice fields hindered weed germination and suppressed the population of most of the germinated weeds. Growth of many of the grass weeds is favoured by saturated and below saturation conditions, while increase in flooding depth and flooding duration encourages broad leaved weeds and sedges (Kent and Johnson 2001). The predominance of the grass species in the experimental site, which are reported to be more sensitive to higher water regimes, must have been another reason for the enhanced WCE of the flooding treatments.

The relative efficiency of the weed management practices during the crop growth period during both seasons was found to be more or less consistent. It was also observed that the weed biomass recorded during the winter season was less than that during rainy season. This was probably because of the carry over effect of the applied treatments, since the

Table 1. Weed flora composition in the experimental field

Family	Scientific name	Common name	Relative density
Araceae	*Cryptocoryne spiralis*	Spiral water trumpet	1.00
Asteraceae	*Eclipta alba*	False daisy	0.25
Commelinaceae	*Cyanotis axillaris (*L.) D. Don	Spreading day flower	0.25
Cyperaceae	*Fimbristylis miliacea*(L.) Vahl.	Globe finger rush	3.00
	Cyperus iria L.	Rice flat sedge	1.00
	Cyperus difformis L.	Umbrellla sedge	1.00
Elatinaceae	*Bergia capensis* L.	Bergia	0.25
Linderniaceae	*Lindernia crustacea* F. Muell.	Malaysian false pimpernel	0.25
Marsileaceae	*Marsilea quadrifolia* L.	Water clover /Water shamrock	2.00
Onagraceae	*Ludwigia perennis* L.	Water primrose	2.00
Poaceae	*Isachne miliacea* Roth ex Roem . et Schult	Blood grass	84.00
	Panicum repense L.	Ginger grass/ Torpedo grass	2.00
Pontederiaceae	*Monochoria vaginalis* (Burm. f.) C. Presl ex Kunth	Pickerel weed	3.00

second crop was taken soon after the rainy season without disturbing the field layout. At 15 DAT the highest WCE was recorded under pre-plant application of oxyflourfen 0.15 kg/ha *fb* one hand weeding but at all the later stages, azimsulfuron 35 g/ ha applied at 15 DAT was significantly superior to the other weed control treatments. However at later stages also the pre-emergent herbicide continued to be the next best treatment probably since it involed integration of chemical and physical methods resulting in broad spectrum of weed control as observed by Sahu *et al.* (2015). When compared to the weedy check, the other two herbicides, *ie*. (bispyribac sodium + metamifop) and fenoxaprop- *p*-ethyl, also recorded >80% WCE. Similar results on broad spectrum WCE of these herbicides have been reported by several earlier researchers (Abraham *et al.* 2010, Rajagopal 2013, Rana *et al.* 2012, Nithya *et al.* 2012, Raj and Syriac 2016).

Effect on crop performance

The results of the present study were indicative of the importance and significance of efficient weed management for enhancing growth, vigour and yield parameters of rice crop (**Table 4** and **5**). Intensive tillage was found to have significant positive effect on the plant height, number of tillers and dry matter production of rice during both seasons, which could

Table 2. Effect of tillage, water regimes and weed management on total weed biomass (g/m^2) in transplanted rice

Treatment	Rainy				Winter			
	15 DAT #	30 DAT #	45 DAT *	60 DAT *	15 DAT #	30 DAT #	45 DAT *	60 DAT *
Tillage								
Intensive tillage	3.39(11.0)	3.29(13.9)	1.23(29.9)	1.51(49.6)	3.12(9.4)	2.96(11.3)	1.15(25.2)	1.47(43.7)
Farmers' practice	3.95(14.9)	3.90(18.5)	1.34(35.3)	1.59(59.6)	3.79(13.7)	3.53(15.2)	1.29(32.0)	1.55(55.1)
LSD(p=0.05)	0.08	0.13	0.02	0.02	0.06	0.07	0.02	0.02
Water regime								
>7.5cm till grain filling stage	3.54(12.0)	3.34(14.1)	1.23(28.8)	1.48(46.6)	3.23(10.0)	3.00(11.5)	1.16(24.7)	1.44(41.7)
> 7.5cm till PI stage	3.57(12.2)	3.39(14.4)	1.24(29.4)	1.53(50.7)	3.26(10.1)	3.10(11.9)	1.16(24.9)	1.49(49.8)
5 cm with intermittent drainage	3.89(14.7)	4.06(20.1)	1.39(39.6)	1.63(66.6)	3.86(14.5)	3.63(16.3)	1.35(36.2)	1.60(70.3)
LSD(p=0.05)	0.09	0.15	0.02	0.03	0.07	0.08	0.03	0.03
Weed management								
Oxyflourfen 0.15 kg/ha *fb* HW	2.25(4.3)	2.22(4.1)	1.13(14.0)	1.35(24.3)	2.07(3.6)	1.99(3.1)	1.07(12.6)	1.32(23.0)
Azimsulfuron 35 g/ha	3.96(14.8)	1.61(1.7)	0.68(5.1)	0.91(8.5)	3.60(12.1)	1.46(1.2)	0.52(3.6)	0.83(07.1)
Bispyribac Na + metamifop 70 g/ha	3.94(14.6)	3.22(9.7)	1.30(20.3)	1.60(40.5)	3.63(12.4)	2.89(7.9)	1.27(19.1)	1.59(39.2)
Fenoxaprop- *p*-ethyl 60 g/ha	3.90(14.3)	3.84(14.1)	1.39(24.8)	1.65(45.7)	3.80(13.6)	3.38(10.7)	1.37(23.9)	1.65(45.3)
Hand weeding at 20 and 40 DAT	3.96(14.8)	2.92(7.8)	1.15(14.4)	1.54(35.0)	3.76(13.3)	2.58(5.8)	1.10(12.9)	1.52(33.7)
Unweeded control	3.98(15.0)	7.78(59.8)	2.06(117.0)	2.23(173.6)	3.87(14.3)	7.17(50.7)	1.99(99.5)	2.16(148.2)
LSD(p=0.05)	0.10	0.15	0.03	0.04	0.10	0.14	0.03	0.05

DAT- days after transplanting, HW- hand weeding, PI-Panicle initiation, # original figures in parenthesis subjected to $(\sqrt{x+1})$ transformation, *original figures in parenthesis subjected to logarithmic transformation

Table 3. Effect of tillage, water regimes and weed management methods on weed control efficiency (%) in transplanted rice

Treatment	Rainy				Winter			
	15 DAT #	30 DAT #	45 DAT #	60 DAT #	15 DAT #	30 DAT #	45 DAT #	60 DAT #
Tillage								
Intensive tillage	6.34(42.2)	8.94(81.8)	8.79(79.7)	8.78(78.6)	7.48(56.9)	8.93(82.1)	8.96(81.5)	8.91(79.9)
Farmers' practice	4.31(22.0)	8.46(75.8)	8.46(76.0)	8.39(74.3)	5.89(37.0)	8.44(75.9)	8.52(76.5)	8.44(74.7)
LSD (p=0.05)	0.35	0.09	0.09	0.05	0.17	0.05	0.06	0.05
Water regime								
>7.5cm till grain filling stage	5.87(37.2)	8.94(81.6)	8.89(80.4)	8.90(79.9)	7.33(54.2)	8.93(81.8)	9.00(81.8)	8.98(80.9)
> 7.5cm till PI stage	5.85(36.2)	8.92(81.1)	8.85(80.0)	8.79(78.2)	7.27(53.4)	8.89(81.0)	8.99(81.8)	8.89(79.3)
5 cm with intermittent drainage	4.24(23.0)	8.24(73.7)	8.14(73.1)	8.07(71.3)	5.45(33.3)	8.23(74.2)	8.22(73.5)	8.16(71.8)
LSD (p=0.05)	0.43	0.11	0.12	0.06	0.21	0.07	0.07	0.06
Weed management								
Oxyflourfen 0.15 kg/ha *fb* HW	8.82(77.3)	9.78(94.6)	9.56(90.5)	9.51(89.5)	9.18(83.6)	9.81(95.1)	9.58(90.8)	9.51(89.5)
Azimsulfuron 35 g/ha	4.56(22.7)	9.94(97.8)	9.88(96.5)	9.87(96.3)	6.65(44.4)	9.95(98.1)	9.92(97.3)	9.89(96.7)
Bispyribac Na + metamifop 70 g/ha	4.71(23.5)	9.39(87.2)	9.34(86.2)	9.14(82.5)	6.56(43.3)	9.40(87.5)	9.33(86.0)	9.11(82.0)
Fenoxaprop- *p*-ethyl 60 g/ha	4.93(25.1)	9.08(81.5)	9.17(83.2)	9.02(80.3)	6.04(37.3)	9.16(83.0)	9.13(82.4)	8.96(79.2)
Hand weeding at 20 and 40 DAT	4.59(22.7)	9.52(89.7)	9.55(90.2)	9.27(84.9)	6.15(38.7)	9.58(90.8)	9.57(90.5)	9.25(84.6)
Unweeded control	-	-	-	-	-	-	-	-
LSD (p=0.05)	0.44	0.13	0.17	0.10	0.25	0.12	0.08	0.06

DAT- Days after transplanting, HW- Hand weeding, PI-Panicle initiation, #original figures in parentheses subjected to $(\sqrt{x+1})$ transformation

Table 4. Effect of tillage, water regimes and weed management methods on growth attributes of transplanted rice

Treatment	Plant height (cm)		Tillers (no./m^2)		Dry matter accumulation at 60 DAT (t/ha)	
	Rainy	Winter	Rainy	Winter	Rainy	Winter
Tillage						
Intensive tillage	99.7	95.0	422.7	496.1	7.34	8.23
Farmers' practice	92.0	87.9	409.7	475.2	6.92	7.78
LSD (p=0.05)	3.94	2.03	7.44	5.63	0.39	0.24
Water regime						
>7.5cm till grain filling stage	99.2	95.7	430.0	485.6	7.31	8.25
> 7.5cm till PI stage	97.5	92.7	431.6	509.9	7.34	8.18
5 cm with intermittent drainage	90.9	85.9	386.9	461.4	6.74	7.56
LSD (p=0.05)	4.83	2.49	9.12	6.89	0.47	0.30
Weed management						
Oxyflourfen 0.15 kg/ha *fb* HW	97.8	93.3	445.8	549.1	7.93	8.80
Azimsulfuron 35 g/ha	98.3	93.9	470.4	581.4	8.11	9.09
Bispyribac Na + metamifop 70 g/ha	97.1	92.7	458.6	524.5	7.70	8.46
Fenoxaprop- *p*-ethyl 60 g/ha	96.1	91.5	448.4	504.1	7.50	8.29
Hand weeding at 20 and 40 DAT	97.3	93.0	442.1	514.8	7.93	9.10
Unweeded control	88.8	84.3	231.7	240.1	3.61	4.26
LSD (p=0.05)	5.81	0.69	15.55	11.16	0.56	0.30

DAT- Days after transplanting, HW- hand weeding, PI –Panicle initiation

Table 5. Effect of tillage, water regimes and weed management methods on yield attributes and yield of transplanted rice

Treatment	Productive tillers (no./m^2)		Thousand seed weight (g)		Sterility (%)		Grain yield (t/ha)		Straw yield (t/ha)	
	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
Tillage										
Intensive tillage	398.2	460.2	25.94	25.87	11.57	11.28	5.23	5.92	6.15	6.78
Farmers' practice	383.9	439.8	22.93	22.39	13.63	13.76	4.71	5.37	6.02	6.86
LSD (p=0.05)	5.59	5.38	0.28	0.51	0.29	0.37	0.22	0.13	ns	Ns
Water regime										
>7.5cm till grain filling stage	405.2	450.4	26.19	25.31	11.53	11.38	5.12	5.86	6.30	7.04
> 7.5cm till PI stage	406.4	473.8	24.13	24.32	12.32	12.20	5.20	5.84	6.18	6.78
5 cm with intermittent drainage	361.7	425.9	22.99	22.76	13.95	13.98	4.59	5.23	5.86	6.65
LSD (p=0.05)	6.84	6.58	0.35	0.62	0.35	0.46	0.27	0.16	NS	NS
Weed management										
Oxyflourfen 0.15 kg/ha *fb* HW	420.1	513.5	25.24	24.75	10.93	10.87	5.58	6.30	6.72	7.54
Azimsulfuron 35 g/ha	443.3	543.6	26.23	26.09	9.64	9.41	5.85	6.61	6.73	7.39
Bispyribac Na + metamifop 70 g/ha	433.3	486.2	24.98	24.54	11.45	11.69	5.24	6.01	6.70	7.29
Fenoxaprop- *p*-ethyl 60 g/ha	422.3	466.2	24.77	24.24	11.88	12.16	5.15	5.78	6.48	7.07
Hand weeding at 20 and 40 DAT	416.5	477.6	25.05	24.36	11.09	11.24	5.65	6.37	6.64	7.70
Unweeded control	211.1	213.1	20.35	20.81	20.59	19.73	2.35	2.79	3.25	3.93
LSD (p=0.05)	10.54	11.37	0.64	1.08	0.46	0.65	0.34	0.23	0.59	0.41

DAT- Days after transplanting, HW- Hand weeding, PI –Panicle initiation

be attributed to the favourable environment created through reduced crop - weed competition as discussed earlier. When compared to the farmers' practice, the plots which received three ploughings recorded significantly more number of productive tillers, thousand grain weight, lower sterility percentage and higher grain yield also while the increase in straw yield was found statistically non-significant. Improvement in growth and yield attributes of rice under reduced resource constraints is well established by earlier workers like Sahu *et al.* (2015).

From the data on effect of water regime on growth and yield attributes of rice, it was evident that when compared to the POP recommendation, the growth attributes were better under the higher levels of water regimes. However, when water ponding was maintained till grain filling stage, the number of tillers was less than that under ponding till panicle initiation stage. Rajagopal (2013) has also reported that in spite of the weed free condition, rice plants under field submergence for longer periods were less vigorous. The positive effect on the yield attributes like number of productive tillers, thousand grain weight and sterility percentage was reflected in the enhanced grain yield also but the improvement in straw yield was non-significant. The beneficial effect of season long weed suppression under deep water ponding on improving crop performance is supported by Ismail *et al.* (2015) who reported that in transplanted rice, under 10, 15 and 20 cm water depth, the yield increase over saturation was to the tune of 84, 85 and 85.5% respectively.

None of the herbicide treatments showed crop phytotoxicity and thus were selective for transplanted rice. The positive effect of reduced weed competition on crop performance was quite evident during both seasons and when compared to the weedy check, all the treated plots recorded significantly superior yield attributes. The maximum values on growth and yield attributes were recorded under azimsulfuron 35 g/ha. During rainy season, the yield enhancement was on par with oxyflourfen 0.15 kg/ha + HW as well as hand weeding twice but was significantly superior to all the other treatments. Evidently reduced competition for growth resources throughout the critical growth stages was helpful in realising the enhanced crop performance. It was also observed that when compared to bispyribac sodium + metamifop and fenoxaprop-*p*-ethyl, crop performance was better under hand weeding twice. However manual weeding being tedious, time consuming and expensive in large scale rice cultivation, farmers are increasingly looking for efficient herbicides for weed management in rice.

It may be concluded that in transplanted rice infested predominantly with grassy weeds, the practices of intensive tillage (three ploughings *fb* puddling) as well as continuous ponding (> 7.5 cm of water) were effective for suppressing weed growth and enhanced crop performance also. Among the herbicides, azimsulfuron 35 g/ha recorded the maximum weed control efficiency and was followed by pre-plant application of oxyflourfen 0.15 kg/ha + one hand weeding.

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