Herbicidal effect on weed growth, crop yield and soil microbes in olitorius jute (*Corchorus olitorius* L.)

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Abstract

A field experiment was conducted during 2007-2008 at Barrackpore on Gangetic alluvium soil to find out the effect of pre-emergence (trifluralin and *S*-metolachlor) and post-emergence (fenoxaprop-p-ethyl, quizalofop ethyl and cyhalofop butyl) herbicides on weed management, growth and fibre yield of olitorius jute, nutrient removal by weeds and effect on soil microbes. The grass and sedges were the dominant weed flora present in the ratio 1: 0.76 on dry weight basis. Trifluralin controlled the grasses but the problem of sedge weeds occurred (97.9 g m^{-2}) and the natural balance of grass:sedge weed complex shifted towards sedge weeds (grass:sedge 1:9). Like trifluralin, the post-emergence grass herbicides (quizalofop ethyl and fenoxaprop-p-ethyl) also allowed sedges to grow. The yield reduction in *olitorius* jute due to weeds was as high as 47.8%. The field was dominated by sedges (along with grass), so, application of *S*-metolachlor @ 0.50 kg ha^{-1} (PE) on soil surface just after jute sowing proved effective in controlling weeds (79.04%), supporting higher jute plant height (252 cm) and achieving higher fibre yield (2.41 Mg ha^{-1}). Weeds in jute field at 45 DAS removed 16.59 kg N, 3.67 kg P_2O_5 and 33.88 kg K_2O ha^{-1}. Nutrient contents were much higher in sedge weeds (1.01% N, 0.34% P_2O_5 and 2.63% K_2O) than the grasses (0.81% N, 0.09% P_2O_5 and 1.22% K_2O). Application of pre and post emergence herbicides in jute affected the total bacteria, actinomycetes and fungi population in soil initially but the microbial population improved gradually and reached to normal level by harvest of jute.

Key words: Herbicides, Jute, Nutrient removal, Soil microbes, Weed management

Introduction

Tossa jute (*Corchorus olitorius* L.), an important fibre yielding cash crop of eastern India is mainly grown in the states of West Bengal, Assam, Odisha, Bihar and eastern part of Uttar Pradesh. Intermittent rain associated with hot and humid climate during the jute growing season in alluvial plains encourages profuse weed growth (Sarkar, 2003) and about 60-75% yield loss may occur in jute (Sarkar et al., 2010). In general, grasses are the dominant weeds in jute. Management of grass and broadleaved weeds in jute by use of pre-emergence herbicides such as trifluralin is possible (Sarkar et al., 2005; Majumdar et al., 2008 and 2010). However, trifluralin is not effective against the sedge weeds which may pose serious problems in some jute areas (Mukherjee et al., 2011). There are a number of post-emergence herbicides like cyhalofop butyl, quizalofop ethyl and fenoxaprop-p-ethyl which showed good weed control in broadleaved field crops like sunflower, soybean and potato (Bedmar, 1997; Ito et al., 1998). Among the available post-emergence herbicides, quizalofop ethyl (5% EC) was found effective to control grass weeds in jute (Ghorai et al., 2004; Bhattacharya et al., 2004). Fenoxaprop-ethyl also showed promise for grass weed control in jute (Sarkar, 2006). Therefore, a

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field experiment was designed to study the effectiveness of the available pre-emergence herbicides having effect on sedges (*S*-metolachlor) and some post-emergence grass herbicides, in *olitorius* jute (cv. JRO 524).

Materials and Methods

A field experiment was conducted for two consecutive years, during 2007 and 2008, at the main farm (22.75°N, 88.43°E and 3.14 m altitude) of Central Research Institute for Jute and Allied Fibres (ICAR), Barrackpore, West Bengal with nine treatments and three replications, laid out in randomized block design with a plot size of 4 m x 3 m. The experimental soil belongs to Typic Ustocrept with sandy loam texture having the general characteristics: *p*H (1:2.5 w/v in water) 7.10, organic carbon 5.52 g kg^{-1}, available N 323, P 28 and K 156 kg ha^{-1}. The nine treatments were T_1: unweeded control, T_2: two hand weedings (HW) at 3 and 5 weeks after sowing (WAS), T_3: trifluralin @ 0.75 kg ha^{-1} one day before sowing (DBS) as pre plant soil incorporation (PPI), T_4: *S*-metolachlor @ 0.50 kg ha^{-1} (1 DBS) as PPI, T_5: *S*-metolachlor @ 0.50 kg ha^{-1} as pre-emergence (just after sowing of jute seed) on soil surface (no soil incorporation), T_6: trifluralin @ 0.50 kg ha^{-1} + S-metolachlor @ 0.50 kg ha^{-1} (1 DBS) PPI, T_7: cyhalofop butyl @ 75 g ha^{-1}, T_8: fenoxaprop-p-ethyl @ 75 g ha^{-1} and T_9: quizalofop ethyl @ 75 g ha^{-1}. All the post emergence herbicides (T_7, T_8 and T_9) were applied at 21 days after sowing (DAS) when the grass weeds were at three-four leaf stage. Jute seed (cv. JRO 524) was sown @ 5 $kgha^{-1}$ in lines with a row spacing of 25 cm in the 2nd week of April and harvested at 110 days crop age. N, P_2O_5 and K_2O @ 60:30:30 $kgha^{-1}$ were applied to the jute crop. The whole amount of P through single super phosphate and K through muriate of potash and 1/3rd N through urea were applied at the time of sowing as basal dose 1/3rd N was applied after first weeding and thinning at 21 DAS and the remaining 1/3rd N was applied after 35 DAS. All other standard agronomic practiced recommended for *olitorius* jute were followed in this experiment. Biometrical observations on jute plant height, fibre yield, type of weeds, and dry weight of weeds were recorded. Soil samples collected at regular intervals were analyzed for changes in soil microbial population over time. The enumeration of soil microbial population was done on agar plate containing appropriate media following serial dilution technique and pour plate method (Pramer and Schmidt, 1966). Thornton's agar media for total bacterial count (Thornton, 1922), Martin's rose Bengal streptomycin agar media for total fungi count (Martin, 1950), and Kenknight and Munaier's media for total actinomycetes counts were used. Weed Control Index (WCI) was calculated as described by Misra and Tosh (1979) and Weed Index (WI) was calculated as given by Gill and Vijayakumar (1966). The statistical analyses of the experimental data were carried out by analysis of variance and means separated by Duncan's multiple range tests.

Results and Discussion

Weed diversity

In the experimental field the predominant grass weeds were *Echinochloa colona* (L.) Link., *Eleusine indica* (L.) Gaertn., *Cynodon dactylon* (L.) Pers. and the predominant sedge was *Cyperus rotundus* L. Grass weeds were common weed flora in jute (Sarkar et al., 2005; Sarkar, 2006; Masumi et al., 2011). In north Bengal condition, sedge weeds infested jute field (Mukherjee et al., 2011).

Effect on weeds

The highest weed dry weight was recorded in unweeded control treatment (185.1 g m^{-2}) and the lowest weed dry weight was found in hand weeding (twice) treatment (35.3 g m^{-2}) which was at par with the weed dry weight recorded with *S*-metolachlor (PE) treatment (38.8 g m^{-2}). In the unweeded control treatment, the grass weed dry weight was 104.9 g

m^{-2} and the sedge dry weight was 80.1 g m^{-2} and the grass:sedge ratio was 1:0.76. Trifluralin @ 0.75 kg ha^{-1} reduced the weight of grasses by 89.6% (T_3). Post emergence application of fenoxaprop-p-ethyl (T_8) or quizalofop ethyl (T_9) controlled 61.2 and 57.9% of grasses respectively, as compared to unweeded control. Post-emergence application of Cyhalofop butyl had little effect in controlling grass or sedge weeds (Table 1). Similar results were obtained with fenoxaprop-p-ethyl (Sarkar, 2006; Ali et al., 2012) and quizalofop ethyl (Ghorai et al., 2004; Bhattacharya et al., 2004; Sarkar, 2006).

Table 1. Effect of pre and post-emergence herbicides on weed dry weight and proportion of weed. (*Two years pooled data*)

Treatments	Dry weight of weeds (g m^{-2})			Relative dominance of weed categories	
	Grass	Sedge	Total	Grass %	Sedge %
T_1: Unweeded Control	104.94	80.14	185.08	56.7	43.3
T_2: Hand weeding twice (21 and 35 DAS)	23.56	11.76	35.32	66.7	33.3
T_3: Trifluralin @ 0.75 kg ha^{-1} (PPI at 1 DBS)	10.88	97.92	108.8	10.0	90.0
T_4: *S*-metolachlor @ 0.50 kg ha^{-1} (PPI at 1 DBS)	54.44	71.28	125.72	43.3	56.7
T_5: *S*-metolachlor @ 0.50 kg ha^{-1} (PE) on soil surface	15.52	23.28	38.8	40.0	60.0
T_6: Trifluralin @ 0.75 kg ha^{-1} + *S*-metolachlor 0.50 kg (PPI)	15.43	100.57	116	13.3	86.7
T_7: Cyhalofop butyl @ 0.075 kg ha^{-1} (POE at 21 DAS)	99.94	57.94	157.88	63.3	36.7
T_8: Fenoxaprop-p-ethyl @ 0.075 kg ha^{-1} (POE at 21 DAS)	40.71	70.21	110.92	36.7	63.3
T_9: Quizalofop ethyl @ 0.075 kg ha^{-1} (POE at 21 DAS)	44.16	66.24	110.4	40.0	60.0
CD (0.05)	9.53	9.16	18.24	-	-

DBS: Days before sowing; DAS: Days after sowing; PPI: pre plant soil incorporation; PE: Pre-emergence just after sowing of jute; POE: Post emergence.

such as fenoxaprop-p-ethyl (T_8) and quizalofop ethyl (T_9) also, the grasses were controlled and the better growth of sedge weeds was observed (60.0 - 63.3% of total weed dry weight). Among the herbicides, only *S*-metolachlor @ 0.50 kg ha^{-1} (PE) applied on soil surface was effective in controlling 71% of sedges in *olitorius* jute. Surprisingly, *S*-metolachlor (@ 0.50 kg ha^{-1}) when applied at 1 DBS as pre-plant soil incorporation, showed little effect in controlling sedge weeds (11.05% WCI). When the grasses were controlled by application of trifluralin, growth of sedges was encouraged. The

Relative dominance of grass and sedge weeds

In the unweeded control treatments, out of the total weed biomass, 56.7% was of grass and the remaining 43.3% was sedge (Table 2). In contrast, earlier Sarkar (2006) reported that the dominant weeds in jute were grasses (96%), and broad leaved (3%) and sedges (1%) were rare in frequency. There were no broadleaved weeds in the present experimental field. Where trifluralin was applied, the grasses were controlled well, which encouraged growth of sedges. In trifluralin treated plots (T_3 and T_6) the grassy weeds were only 10.0 – 13.3% of the population and the sedge weeds were 86.7 - 90.0%. In case of post-emergence grass killing herbicides dry weights of sedges were 22.0 – 25.5% more in trifluralin treated plots (T_3 and T_6). In normal unweeded condition the dry weight ratio of grass: sedge was 1:0.76, which increased to 1:9 in trifluralin treated plots. In case of post-emergence application of grass controlling herbicides also, the grass: sedge ratio increased to 1:1.72 and 1:1.50 for fenoxaprop-p-ethyl and quizalofop ethyl treatments, respectively.

Nutrient removal by weeds

It is well established that weeds remove huge amount of nutrients from crop fields and the same is true for jute as well. It was observed that weeds

Table 2. Effect of different weed management methods on nutrient removal by weeds at 45 DAS in *olitorius* jute. (*Two years pooled data*)

Treatments	N removal (kg ha^{-1})			P_2O_5 removal (kg ha^{-1})			K_2O removal (kg ha^{-1})		
	Grass	Sedge	Total N	Grass	Sedge	Total P_2O_5	Grass	Sedge	Total K_2O
T_1: Unweeded Control	8.50	8.09	16.59	0.94	2.72	3.67	12.80	21.08	33.88
T_2: Hand weeding twice (21 and 35 DAS)	1.91	1.19	3.10	0.21	0.40	0.61	2.87	3.09	5.97
T_3: Trifluralin @ 0.75 kg ha^{-1} (PPI at 1 DBS)	0.88	9.89	10.77	0.10	3.33	3.43	1.33	25.75	27.08
T_4: *S*-metolachlor @ 0.50 kg ha^{-1} (PPI at 1 DBS)	4.41	7.20	11.61	0.49	2.42	2.91	6.64	18.75	25.39
T_5: *S*-metolachlor @ 0.50 kg ha^{-1} (PE) on soil surface	1.26	2.35	3.61	0.14	0.79	0.93	1.89	6.12	8.02
T_6: Trifluralin @ 0.75 kg ha^{-1} + *S*-metolachlor 0.50 kg (PPI)	1.25	10.16	11.41	0.14	3.42	3.56	1.88	26.45	28.33
T_7: Cyhalofop butyl @ 0.075 kg ha^{-1} (POE at 21 DAS)	8.10	5.85	13.95	0.90	1.97	2.87	12.19	15.24	27.43
T_8: Fenoxaprop-p-ethyl @ 0.075 kg ha^{-1} (POE at 21 DAS)	3.30	7.09	10.39	0.37	2.39	2.75	4.97	18.47	23.43
T_9: Quizalofop ethyl @ 0.075 kg ha^{-1} (POE at 21 DAS)	3.58	6.69	10.27	0.40	2.25	2.65	5.39	17.42	22.81

DAS: Days after sowing; DBS: Days before sowing; PE: Pre-emergence; PPI: Pre plant soil incorporation; POE: Post emergence

present at 45 DAS in *olitorius* jute field can remove 16.59 kg N, 3.67 kg P_2O_5 and 33.88 kg K_2O ha^{-1} (Table 2). The lowest N removal by weeds were recorded in hand weeding (twice) treatments (3.10 kg N ha^{-1}) followed by *S*-metolachlor (T_5) treated plots (3.61 kg ha^{-1}). The lowest P_2O_5 removal by weeds was recoded with two hand weeding treatment (0.61 kg ha^{-1}) closely followed by *S*-metolachlor treatment (0.93 kg ha^{-1}). Out of the total P_2O_5 removal by weeds (3.67 kg ha^{-1}), sedges removed 74.1% and grass removed 25.9%. Sedges removed 189.4% more P_2O_5 as compared to the phosphate removal by grassy weeds. The total K_2O removal by weeds at 45 DAS in jute was 33.88 kg ha^{-1}, of which 62.2% was removed by sedges only. The minimum K_2O removal was in the hand weeding treatments (5.97 kg ha^{-1}) which was followed by the K_2O removal in *S*-metolachlor treated plot (8.02 kg ha^{-1}). The sedge weeds removed 64.7% more K_2O than the grasses (12.80 kg ha^{-1}). Nutrient contents were much higher in sedge weeds (1.01% N, 0.34% P_2O_5 and 2.63% K_2O) than the grasses (0.81% N, 0.09% P_2O_5 and 1.22% K_2O). Therefore, presence of sedge weeds in jute field is more detrimental than grasses as the former removes greater amount of nutrients from soil.

Effect on crop

Weed control index (WCI)

The highest WCI was recorded in hand weeding (twice) treatments (80.92%) closely followed by *S*-metolachlor (PE) treatment (79.04%). Post-emergence grass controlling herbicides (fenoxaprop-p-ethyl and quizalofop ethyl) controlled the grasses but due to presence of sedge weeds in the weed complex, the WCI were 40.07 (fenoxaprop-p-ethyl) and 40.45% (quizalofop ethyl) only (Table 3).

Jute plant height

The highest plant height at harvest (110 days) was recorded in hand weeding (twice) treatments (254 cm) which was at par with the plant height obtained in *S*-metolachlor (252 cm). The lowest height was recorded in unweeded plots (199 cm).

Jute fibre yield

The highest fibre yield was obtained in hand weeding (twice) treatment (2.42 Mg ha^{-1}) which was at par with the fibre yield obtained in *S*-metolachlor

Table 3. Effect of pre and post-emergence herbicides on weed control, weed index, growth and yield of jute. (*Two years pooled data*)

Treatments	Weed Control Index (%)		Plant Height (cm)	FibreYield (Mg ha^{-1})	Weed Index (%)
	21 DAS	45 DAS			
T_1: Unweeded Control	-	-	199	1.26	47.8
T_2: Hand weeding twice (21 and 35 DAS)	74.6	80.92	254	2.42	-
T_3: Trifluralin @ 0.75 kg ha^{-1} (PPI at 1 DBS)	33.6	41.21	233	1.79	25.8
T_4: *S*-metolachlor @ 0.50 kg ha^{-1} (PPI at 1 DBS)	22.7	32.07	232	1.88	22.3
T_5: *S*-metolachlor @ 0.50 kg ha^{-1} (PE) on soil surface	75.3	79.04	252	2.41	0.2
T_6: Trifluralin @ 0.75 kg ha^{-1} + *S*-metolachlor 0.50 kg (PPI)	32.6	37.32	239	2.25	6.9
T_7: Cyhalofop butyl @ 0.075 kg ha^{-1} (POE at 21 DAS)	-	14.70	233	2.11	12.7
T_8: Fenoxaprop-p-ethyl @ 0.075 kg ha^{-1} (POE at 21 DAS)	-	40.07	249	2.33	3.7
T_9: Quizalofop ethyl @ 0.075 kg ha^{-1} (POE at 21 DAS)	-	40.35	244	2.33	3.7
CD (0.05)	-	-	19.61	0.30	-

DBS: Days before sowing; DAS: Days after sowing; PPI: pre plant soil incorporation; PE: Pre-emergence just after sowing of jute; POE: Post emergence; WCI: Weed control index, WI: Weed index

PE (2.41 Mg ha^{-1}), fenoxaprop-p-ethyl (2.33 Mg ha^{-1}) and quizalofop ethyl (2.33 Mg ha^{-1}). The lowest fibre yield was recorded with unweeded control plots (1.26 Mg ha^{-1}). Herbicidal weed management increased the jute fibre yield by 91.3% over unweeded control. Majumdar et al. (2008) reported 117.8% increase in jute (cv. JRO 524) fibre yield due to weed management by pre-emergence herbicide (trifluralin).

Yield reduction due to weeds / Weed Index

The minimum yield reduction due to weeds *i.e.*, Weed Index (WI) was noted in *S*-metolachlor treatments (0.2%) closely followed by fenoxaprop-p-ethyl (3.7%) and quizalofop ethyl (3.7%). *S*-metolachlor @ 0.50 kg ha^{-1} when applied as PE on soil surface was very effective in controlling weeds and recorded a WI of 0.2%; in contrast, the same herbicide (at the same dose) when used as pre-plant soil incorporation at 1DBS could not achieve the desired level of weed control and hence the yield reduction was higher (22.3% WI).

Effect on soil microbes

Effect of different weed management methods including pre and post emergence herbicides were studied in the soil microbial population namely total bacteria, actinomycetes and fungi in jute soil. Initial values for total bacteria, total actinomycetes and total fungi per g of dry soil were 21.71×10^5 CFU, 69.15×10^4 CFU and 125.89×10^3 CFU, respectively (Table 4).

Pre-emergence herbicides such as trifluralin and metolachlor either singly or in combination reduced the total soil bacteria count by 36.2 - 69.1% at 7 days after application. At 21 DAS, the total bacterial population increased by 52.9% in trifluralin (T_3) treated plots. At 45 DAS, the total bacterial count was reduced to the tune of 64.9, 62.4 and 58.9% by quizalofop ethyl, cyhalofop butyl and fenoxaprop-p-ethyl, respectively. There was downpour (33 rainy days in 62 days) during July and August (607.2 mm *i.e.,* 50% of the total annual rainfall) and at harvest (2nd week of August), the soil was inundated due to frequent rains resulting in decreased bacterial and fungal population. Unger et al. (2009) reported that flood conditions decreased microbial biomass and markers for aerobic bacteria, Gram-negative bacteria, Gram-positive bacteria, and mycorrhizal fungi. At harvest, in all the treatments (except in T_6) the bacterial population was comparable with the control treatment.

Table 4. Effect of different weed management methods on soil microbes in *olitorius* jute. (*Two years pooled data*)

Treatments	Bacteria (× 10^5 CFU)				Actinomycetes (× 10^4 CFU)				Fungi (× 10^3 CFU)			
	7 DAS	21 DAS	45 DAS	Harvest	7 DAS	21 DAS	45 DAS	Harvest	7 DAS	21 DAS	45 DAS	Harvest
*T_1	20.13	22.98	21.33	6.31	73.24	80.46	79.86	76.92	131.85	139.21	32.11	13.87
T_2	21.21	20.87	18.91	5.04	75.12	81.32	85.75	142.50	132.61	143.53	30.26	13.71
T_3	6.71	33.20	23.12	6.16	32.70	53.64	127.36	166.46	85.53	137.93	37.83	20.17
T_4	10.06	19.16	19.33	6.22	36.89	56.19	133.25	160.15	124.95	116.22	49.60	16.39
T_5	10.69	17.88	24.59	7.16	35.22	153.25	137.03	185.37	113.84	25.54	45.39	17.65
T_6	13.84	20.43	25.64	3.88	27.04	104.72	128.21	110.97	105.03	20.43	57.59	20.19
T_7	19.85	20.69	8.17	5.98	72.08	76.89	62.13	85.75	129.27	138.08	42.16	25.22
T_8	20.03	21.07	8.92	6.29	75.11	78.23	67.27	108.45	134.17	137.29	44.09	16.43
T_9	19.88	20.11	7.61	5.02	71.59	75.11	61.02	88.27	133.22	138.00	43.11	20.17
Initial values	21.71				69.15				125.89			

*Details of treatments are given under Table 1; DAS: Days after sowing; CFU: Colony forming units

The total actinomycetes population was reduced initially by the application of pre-emergence herbicides. The depression was in the order trifluralin + S-metolachlor (60.9%) > trifluralin (52.7%) > *S*-metolachlor PE (49%) > *S*-metolachlor PPI (46.6%). At harvest the detrimental effect of pre-emergence herbicides on actinomycetes population was nullified. As compared to the hand weeding (twice) treatment, at harvest, post-emergence herbicides recorded lower total actinomycetes population in the order of cyhalofop butyl (39.8%) > quizalofop ethyl (38%) > fenoxaprop-p-ethyl (23.9%). However, the said actinomycetes populations in post-emergence herbicide treated plots were normal as compared to the unweeded treatments.

At 7 DAS, the total fungi population was lower by 32% in trifluralin treatment but the same reached the normal level within 3 weeks. *S*-metolachlor did not affect the total fungi population. At harvest there were not much difference in the total fungi population among the different weed management treatments. The findings on soil microbial population dynamics of this study corroborates the observations of Majumdar et al. (2008).

It may be inferred from the field study that if the jute field is dominated by sedges (along with grass), application of *S*-metolachlor @ 0.50 kg ha^{-1} (PE) on soil surface just after sowing of jute is effective in controlling weeds (79.04%), supporting higher jute plant height (252 cm) and achieving higher fibre yield (2.41 Mg ha^{-1}). Weeds in jute field at 45 DAS remove 16.59 kg N, 3.67 kg P_2O_5 and 33.88 kg K_2O/ha. Nutrient contents were much higher in sedge weeds (1.01% N, 0.34% P_2O_5 and 2.63% K_2O) than the grasses (0.81% N, 0.09% P_2O_5 and 1.22% K_2O). Therefore, sedge weeds are more detrimental than grasses in jute field. Application of pre and post emergence herbicides in jute affects the total bacteria, actinomycetes and fungi population in soil initially but the count improves gradually and reaches normal level by harvest of jute.

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