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Integrated Use of Herbicide and Weed Mulch with Closer Spacing for Weed Management in Dry Direct Seeded Rice

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Abstract

The field experiments were conducted during the wet season of 2015 and 2016 (June to October) at Agricultural Farm, Institute of Agriculture, Visva-Bharati, Sriniketan, India to study the impact of integrated use of weed mulch and herbicide with closer spacing on weed growth and yield of direct seeded dry sown rice (*Oryza sativa* L.) cultivar MTU 1010. The experiment consisted of twelve treatments involving sole or integrated application of pre-emergence herbicide pendimethalin, mulching with water hyacinth and *Indigofera* weed and closer row spacing of 20 cm. The experiment was laid out in randomized block design with three replications. The experimental field was infested with 14 weeds out of which the predominant species were *Cynodon dactylon*, *Echinochloa colona*, *Cyperus iria*, *Ludwigia parviflora*, *Hydrolea zeylanica*, *Spilanthes acmella*, *Alternanthera sessilis*, *Commelina benghalensis* and *Cyanotis axillaris*. Integration of pendimethalin at 0.75 kg ha^{-1} and mulching with water hyacinth and closer spacing reduced weed dry weight by 75.92% over the weedy check. Integration of mulching with water hyacinth and closer spacing increased grain yield by 37.27 and 41.12% over sole application of pendimethalin and water hyacinth mulch, respectively. Weed competition resulted in 57% reduction in grain yield of rice. Hand weeding twice (25 and 45 DAS) had a significant effect on the reduction of weed density and dry weight and increasing grain yield of rice which was followed by application of pendimethalin 0.75 kg ha^{-1} along with mulching with water hyacinth at a closer row spacing of 20 cm.

Keywords: Closer spacing, DSR, *Indigofera*, pendimethalin, water hyacinth, weedmulch

1. Introduction

Rice (*Oryza sativa* L.) is one of the most important leading cereal crops of the world and more than 60% of the global population depends on it for daily sustenance. Conventional puddled transplanted rice (PTR) is a major source of greenhouse gas (GHG), particularly methane, causing global warming (Brye et al., 2013) in addition to higher use of water energy and input (Neog et al., 2015; Mohammad et al., 2018). Direct-seeded rice (DSR) is emerging as an efficient, economically viable, and environmentally promising alternative to PTR in Asia because in this crop establishment method saving of resources is possible which are becoming increasingly scarce (Kumar and Ladha, 2011; Gathala et al., 2013; Ladha et al., 2016; Rao et al., 2017). From global warming point of view, DSR offers both mitigation of climate change by reducing green house

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gas (GHG) emissions and adaptation to its effects of water shortage, as well as the weak and erratic nature of monsoon conditions (Pathak et al., 2013; Padre et al., 2016). The use of human labour is also reduced to 45% and tractor use to 58% in the DSR compared to PTR. The yields are comparable with transplanted rice if the crop is properly managed (Pathak et al., 2013). In addition, there is approximately 30-40% saving of water in dry DSR than conventional PTR (Yadav et al., 2011). Despite its many benefits, there are some risks associated with DSR which limit its wide-scale adoption and the possibility of attaining optimal grain yields using this method. One of these risks includes higher weed infestation. The productivity of the DSR is often reported to be lower, mainly due to problems associated with weed management. Aerobic soil conditions and dry-tillage practices, besides alternate wetting and drying conditions, are conducive for germination and growth of highly competitive weeds, which cause grain yield losses of 50–91% (Duary et al., 2005; Naresh et al., 2011; Mathew et al., 2013; Verma et al., 2016; Chakraborti et al., 2017a, 2017b; Dash and Duary, 2020). Application of herbicide is easy, rapid and more effective than other methods. The use of herbicide is becoming more popular in DSR because it saves labour and reduces the cost of cultivation (Singh et al., 2016; Dash and Duary, 2020). But there has been grave apprehension about the sole dependence on herbicide use due to the development of herbicide resistance, the shift of weed flora rendering the herbicide inefficient in long run (Duary, 2008) and the emerging negative environmental footprints (Shekhawat et al., 2020).

Cultural approaches, based on the understanding of weed biology are viable options in integrated weed management programs. Use of stale seedbed technique, tillage practices, use of weed competitive varieties, narrow crop row spacing and high crop seed rate and use of crop residue as mulches are the major approaches for integrated weed management (Fatima and Duary, 2020; Fatima et al., 2020). There is also a scope of integrating herbicides with cultural practices to improve the sustainable use of herbicides (Sharma and Singh, 2016). Preemergence herbicides like pendimethalin and several postemergence herbicides have been reported to provide a good degree of weed control in direct seeded rice. In addition, because of the variability in the growth habit of weeds, any single method of weed control cannot provide effective and season-long control in DSR. In this situation, there is a need to integrate other weed management strategies with herbicide. With this perspective, the present experiment was undertaken to study the impact of weed management in dry direct seeded rice with an integrated approach using pre-emergence herbicide and weed mulch with closer crop spacing.

2. Materials and Methods

2.1. Experimental period and location

A field experiment was conducted at Agricultural Farm, Institute of Agriculture, Visva-Bharati University, Sriniketan, West Bengal, India, during the wet season of 2015 and 2016 from June to October. The Agricultural Farm falls under sub-humid, sub-tropical belt of the western part of West Bengal, India and is situated at about $23^0 39'$ N latitude and $87^0 42'$ E longitude with an average altitude of 58.9 m above the mean sea level. The soil of the experimental site was sandy loam in texture with pH 5.1, low in organic carbon (0.40%), available nitrogen (289.00 kg ha^{-1}), available phosphorus (8.50 kg ha^{-1}) and medium in available potassium (56.25 kg ha^{-1}).

2.2. Experimental design and treatments details

The experiment was laid out in randomized block design with twelve treatments viz. Pendimethalin at 0.75 kg ha^{-1} as pre-emergence (T_1), Mulching with water hyacinth weed at 20 t ha^{-1} (T_2), Mulching with *Indigofera* weed at 16 t ha^{-1} (T_3), Pendimethalin at 0.75 kg ha^{-1} as pre-emergence+mulching with water hyacinth weed (T_4), Pendimethalin at 0.75 kg ha^{-1} as pre-emergence+mulching with *Indigofera* weed (T_5), Closer spacing (20 cm row to row)+pendimethalin at 0.75 kg ha^{-1} as pre-emergence (T_6), Closer spacing (20 cm row to row)+mulching with water hyacinth weed (T_7), Closer spacing (20 cm row to row)+mulching *Indigofera* weed (T_8), Closer spacing (20 cm row to row)+pendimethalin at 0.75 kg ha^{-1} as pre-emergence+mulching with water hyacinth weed (T_9), Closer spacing (20 cm row to row)+pendimethalin at 0.75 kg ha^{-1} as pre-emergence+mulching with *Indigofera weed* (T_{10}), Hand weeding twice at 25 and 45 DAS (T_{11}) and Weedy (T_{12}) which were replicated thrice to study the effect of weed management in dry direct seeded rice with integrated approach using pre-emergence herbicide and weed mulch with closer spacing.

2.3. Package and practices

The rice cultivar MTU 1010 was raised following the standard recommended package of practices. The crop was fertilized with 80:40:40 kg ha^{-1} of $N:P_2O_5:K_2O$, respectively. Pre-emergence herbicide pendimethalin was applied using a knapsack sprayer and the spray volume was 500*l* of water ha^{-1}. Observations on weeds were recorded by placing the quadrat of size 50×50 cm^2.

2.4. Weed control efficiency and Weed index

Weed control efficiency (WCE) was computed using the dry weight of weeds. To determine WCE of individual treatment, the following formula was used and expressed in percentage.

$$WCE=(WDC-WDT)/WDC\times100$$

Where, WCE=Weed control efficiency, WDC=Weed dry matter (aerial part) in weedy check plot and WDT=Weed dry matter in treated plot.

Weed index (WI) was determined by using the following formula and expressed in percentage.

$$WI=(Y_{WFC}-Y_T)/Y_{WFC}\times100$$

Where, WI is the Weed index, Y_{WFC}=Grain yield of the crop in weed free check, Y_T=Grain yield of the crop in plot under treatment.

2.5. *Methods of statistical analysis*

The experimental data relating to each character of crop and weed were analyzed by the technique of "Analysis of variance" using MSTAT statistical package and significance was tested by variance ratio i.e. value at 5% level of significance as described by Gomez and Gomez (2010). Pooled analysis of two year's data on weed growth and crop parameters has been done and presented in tables.

3. Results and Discussion

3.1. *Effect on weed density*

The experimental field was infested with 14 weed species, out of which *Digitaria sanguinalis, Echinochloa colona* was the most predominant among Grasses, *Alternanthera sessilis*, *Heydiotis corymbosa, Spilanthes acmella, Ludwigia parviflora, Cyanotis axillaris, Hydrolea zelylanica* among broadleaved and *Cyperus iria* and *Cyperus compressus* among sedges. In both the years, as expected, the density of grass, Broadleaved and sedge was the highest in weedy check (T_{12}). Integration of weed mulch and closer spacing exhibited better performance with respect to reduction of weed density as compared to sole application of pre-emergence herbicide pendimethalin. Hand weeding twice at 25 and 45 DAS (T_{11}) registered significantly the lowest density of weeds at 60 DAS and was followed by closer spacing (20 cm row to row)+pendimethalin at 0.75 kg ha^{-1} as pre-emergence+mulching with water hyacinth weed (T_9) (Table 1). Sole application of pendimethalin (T_1) and mulching with water hyacinth (T_2) was able to reduce the total weed density of DSR by 51.53 and 54.54% over weedy check, respectively when pooled over the years. Integration of mulching water hyacinth with closer spacing reduced the total weed density by 58.07% over the weedy check. Further integration of pendimethalin reduced weed density by 64.57%. The results are in consonance with Fatima and Duary (2020). Narrow row spacing of rice reduces light availability to weed by fast canopy cover (Chauhan and Johnson, 2011).

3.2. *Effect on weed biomass*

As expected, the dry weight of different categories of weed

Table 1: Effect of weed management practices on category wise and total weed density and dry weight and weed control efficiency of different treatments at 60 DAS (Pooled data)

Treatments	Weed density (Number m^{-2}) at 60 DAS				Weed dry weight (g m^{-2}) at 60 DAS				WCE (%)
	Grass	Sedge	BLW	Total	Grass	Sedge	BLW	Total	
T_1-Pendimethalin at 0.75 kg ha^{-1} as pre-emergence (PE)	19.67	34.33	85.38	139.37	8.29	13.83	20.74	42.86	59.9
T_2-Mulching with water hyacinth (WH) weed at 20 t ha^{-1}	21.67	24.00	87.05	130.71	8.01	19.99	19.95	47.95	55.2
T_3-Mulching with Indigofera weed at 16 t ha^{-1}	31.67	43.33	127.88	202.87	13.63	21.36	27.31	62.29	41.7
T_4-Pendimethalin at 0.75 kg ha^{-1} as PE+mulching with WH weed	15.84	18.17	78.21	112.21	7.02	12.06	15.77	34.84	67.4
T_5-Pendimethalin at 0.75 kg ha^{-1} as PE+ mulching with Indigofera weed	27.33	31.67	113.88	172.87	9.92	15.56	18.46	43.94	58.9
T_6-Closer spacing (20 cm row to row)+pendimethalin at 0.75 kg ha^{-1} PE	17.67	22.34	79.55	119.55	6.91	10.87	18.46	36.23	66.1
T_7-Closer spacing (20 cm row to row)+mulching with WH weed	18.17	21.00	81.38	120.55	6.44	14.42	13.44	34.30	67.9
T_8-Closer spacing (20 cm row to row)+mulching Indigofera weed	24.17	33.00	108.54	165.71	12.16	14.32	22.97	49.45	53.7
T_9-Closer spacing (20 cm row to row)+pendimethalin at 0.75 kg ha^{-1} as PE+mulching with WH weed	15.17	14.50	72.21	101.87	5.84	7.61	12.30	25.74	75.9
T_{10}-Closer spacing (20 cm row to row)+pendimethalin at 0.75 kg ha^{-1} as PE+mulching with Indigofera weed	25.00	27.00	75.21	127.21	9.43	16.30	19.53	45.25	57.7
T_{11}- Hand weeding twice at 25 and 45 DAS	7.67	11.17	48.71	67.54	4.26	4.92	10.34	19.51	81.8
T_{12}-Weedy	37.17	45.67	204.71	287.54	25.13	30.23	51.55	106.91	0.0
SEm±	2.25	3.08	5.69	7.13	0.86	1.17	1.60	2.37	-
CD (p=0.05)	6.59	9.04	16.71	20.92	2.52	3.41	4.67	6.95	-

at 60 DAS was the highest in weedy check plots as evident from the pooled data presented in Table 1. Among all the treatments, hand weeding twice at 25 and 45 DAS (T_{11}) registered lower biomass of all categories (grassy, broadleaved and sedges) of weed with 81.8% total weed control efficiency (WCE). Integration of pre-emergence herbicide pendimethalin at 0.75 kg $ha^{-1}$and mulching with water hyacinth with closer spacing (20 cm row to row) (T_9) also reduced dry weight of weed by 75.92% over the weedy check. However, the sole application of pendimethalin (T_1) and water hyacinth weed (T_2) showed only 59.91 and 55.14% reduction in total weed biomass, respectively. A similar result was also observed by Verma et al. (2016) who observed that integration of physical, chemical, and cultural method resulted in lower weed density and dry matter accumulation in DSR. Choudhary and Dixit (2018) reported 40-50% control of weed by sole application of pendimethalin. The effect of different weed management practices on weed dry matter accumulation (g m^{-2}) of different weed categories at 60 days of crop growth has been presented in Table 1. The results suggest that weed biomass can be significantly reduced by the use of weeds like water hyacinth (55.2% WCE) and *Indigoera* (41.7% WCE) as mulch, at least for partial weed control, where these weeds are abundantly available. However, the use of mulch alone did not suppress the growth of weeds satisfactorily as the plots mulched with weeds still had 45-58% of the weed biomass compared with weedy. Weed mulch can substantially suppress the growth of weeds in DSR when used integrated with other management strategies. The reasons may be a reduction in light transmittance, physical barrier by the mulch cover and release of allele-chemicals (Teasdale and Mohler, 1993).

3.3. Effect of treatments on crop growth and yield

The plant height varied significantly with different treatments at 60 and 90 DAS. The highest plant height both at 60 and 90 DAS was recorded under hand weeding twice (at 25 and 45 days after sowing) and was on par with integrated use of pre-emergence herbicide pendimethalin at 0.75 kg ha^{-1} and water hyacinth mulching with closer spacing (T_9) (Table 2). The effect of different weed management practices on panicle length and yield components of rice is given in Table 2. Integration of different weed management practices had a significant effect on various yield components like number

Table 2: Plant height, panicle length, yield components, yield of rice and weed index of different weed management practices (Pooled data)

Treatments	Plant height (cm)		Panicle length (cm)	No. of panicles m^{-2}	No. of filled grains $panicle^{-1}$	Test weight (g)	Grain yield (t ha^{-1})	Weed index (%)
	60 DAS	90 DAS						
T_1-Pendimethalin at 0.75 kg ha^{-1} as pre-emergence (PE)	63.0	104.7	23.58	144.00	69.84	21.56	2.12	47.3
T_2-Mulching with water hyacinth (WH) weed at 20 t ha^{-1}	62.2	104.2	25.83	159.50	74.00	21.59	1.99	50.5
T_3-Mulching with Indigofera weed at 16 t ha^{-1}	63.2	104.9	22.23	161.67	67.67	21.24	2.07	48.5
T_4-Pendimethalin at 0.75 kg ha^{-1} as PE+mulching with WH weed	65.2	106.0	26.39	162.00	79.34	21.77	2.37	41.2
T_5-Pendimethalin at 0.75 kg ha^{-1} as PE+ mulching with Indigofera weed	63.7	105.0	25.61	198.67	72.17	21.58	2.24	44.4
T_6-Closer spacing (20 cm row to row)+pendimethalin at 0.75 kg ha^{-1} PE	60.3	107.7	24.05	195.00	70.83	21.22	2.36	41.3
T_7-Closer spacing (20 cm row to row)+mulching with WH weed	63.9	104.1	23.40	207.50	73.33	21.24	2.39	40.7
T_8-Closer spacing (20 cm row to row)+mulching Indigofera weed	58.5	105.2	22.93	191.67	64.17	21.02	2.60	35.4
T_9-Closer spacing (20 cm row to row)+pendimethalin at 0.75 kg ha^{-1} as PE+mulching with WH weed	66.8	110.7	24.76	230.84	97.17	22.55	3.38	15.9
T_{10}-Closer spacing (20 cm row to row)+pendimethalin at 0.75 kg ha^{-1} as PE+mulching with Indigofera weed	66.4	108.1	23.58	185.00	72.33	21.79	2.80	30.3
T_{11}- Hand weeding twice at 25 and 45 DAS	72.4	114.9	24.22	253.00	104.17	21.97	4.02	0.0
T_{12}-Weedy	61.6	98.5	21.13	123.34	61.34	21.08	1.72	57.3
SEm±	1.9	2.0	0.97	15.32	2.33	0.54	0.18	-
CD (p=0.05)	5.8	5.9	NS	44.93	6.73	NS	0.53	-

of panicles m^{-2}, number of grain $panicle^{-1}$ and the grain yield of rice. But the treatments had no significant effect in terms of panicle length and test weight (Table 2). The number of grains $panicle^{-1}$ was the highest in hand weeding twice at 25 and 45 DAS which was followed by closer spacing (20 cm row to row)+pendimethalin at 0.75 kg ha^{-1} as pre-emergence+mulching with water hyacinth weed (T_9). As expected, grain yield was higher in the treated plots than in the non-treated plots. Unweeded check lowered the grain yield by 57% due to severe weed competition from initial stages. Verma et al. (2016) also reported 60% loss of grain yield due to weed competition in direct seeded rice. The highest grain yield (4.02 t ha^{-1}) was recorded with hand weeding twice (at 25 and 45 days after sowing) and was followed by integrated use of pre-emergence herbicide pendimethalin at 0.75 kg $ha^{-1}$with water hyacinth mulching and closer spacing (3.38 t ha^{-1}) as evident from the pooled data presented in Table 2. Integration of mulching water hyacinth with closer spacing increased grain yield by 37.27 and 41.12% over sole application of pendimethalin and water hyacinth mulch, respectively when pooled over the years. Compared with the treatment in which only herbicide was applied, the integration (herbicide plus water hyacinth mulch with closer spacing) resulted in 59.43% greater yield of rice. Integrated use of pre-emergence herbicide pendimethalin at 0.75 kg ha^{-1} with water hyacinth mulching and closer spacing also registered the lowest weed index (15.9%) and was followed by T_{10} (30.3%) (Table 2). An increase in yield of rice due to the effect of mulch has also been reported by Yadav et al. (2018) and closer row spacing increased grain yield of DSR as reported by (Mahajan and Chauhan, 2011). These results support previous views that integrated use of herbicide with other management strategies could result in a greater yield advantage over the use of herbicide alone. The results of the present study suggest that the use of readily available weed biomass as mulch can suppress seedling emergence and weed growth. Though herbicide is an important component for weed management in dry-DSR; however, herbicide alone may not provide complete and season-long weed control (Chauhan, 2012). Therefore, integrating herbicide with other weed management strategies may increase weed control and grain yield in DSR. We used mulch of water hyacinth and *Indigofera* weeds which are abundantly available in nearby areas of the fields. Such an option would be more practical at least for partial weed control for smallholding farmers who do not have enough resources to use multiple herbicides (Singh et al., 2008).

4. Conclusion

Integration of pre-emergence herbicide pendimethalin at 0.75 kg ha^{-1} and mulching with water hyacinth along with closer crop spacing (20 cm row to row) reduced the weed infestation by 76% and appeared as a promising approach for managing broad spectrum weeds and obtaining higher grain yield of direct seeded dry sown rice in the lateritic belt of West Bengal.

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