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Reduction of soil weedseedbank with increased yield in dry direct-seeded rice through weed management

P. Nagarjun*, G.N. Dhanapal, M.T. Sanjay, S.B. Yogananda and R. Muthuraju[1]

Department of Agronomy, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka 560065, India

[1]Department of Agriculture Microbiology, GKVK, Bengaluru, Karnataka 560065, India

**Email: nagarjunp009@gmail.com*

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ABSTRACT

Rice cultivation always have a significant role in food and livelihood security. The predictions of increasing water deficiency under a changing climate and overcoming labor shortages in agriculture have brought a change in rice cultivation from conventionally flooded transplanting to direct-seeded rice (DSR) but weeds are the major production constrain in direct-seeded rice. Keeping these facts in view a field study was conducted during rainy season *(Kharif)*, 2016 and 2017 at the Main Research Station, Hebbal, Bengaluru, India to study the effect of different weed management treatments in dry direct-seeded rice (upland condition) on growth, yield and soil weed seedbank as measured by emergence of weed seedlings. Among various weed management treatments, hand weeding at 20, 40 and 60 DAS recorded significantly highest paddy grain and straw yield in hand weeding at 20, 40 and 60 DAS (5.50 and 7.22 t/ha, respectively) and found at par with application of bensulfuron-methyl + pretilachlor as pre-emergence *fb* bispyribac-sodium (5.39 and 7.16 t/ha, respectively). Weedy check recorded significantly lowest yield (1.40 and 2.32 t/ha, respectively). At different intervals significantly the lowest weed seedlings emergence was noticed from the soils collected from different depths in hand weeded plots during both the years. Among various herbicide combinations, pre-emergence application of bensulfuron-methyl + pretilachlor followed by bispyribac-sodium recorded the lowest weed seedbank, as measured by germination of weed seeds and weed seedling emergence, followed by bensulfuron-methyl + pretilachlor and triafamone + ethoxysulfuron. Significantly the highest weed seedbank was noticed from soil collected from weedy check.

INTRODUCTION

Rice production systems are enduring numerous changes and one of such changes is modification from transplanted rice to direct seeding. Direct-seeding of rice (DSR) is increasing rapidly in Asia as the farmers seek high productivity and profitability to offset increasing costs and shortage of farm labour (Pandey and Valesco 2002, Rao *et al.* 2007, 2017). Conventionally, paddy is established by transplanting seedlings in puddled soils, which demands a huge amount of water and labour. The way of direct-seeding evades the transplanting and puddling operations. The major restriction in the effective cultivation of DSR in tropical countries is heavy infestation of weeds which often results in reduction in grain yield from 50-91% (Rao *et al.* 2007).

Soil weed seedbanks are reserves of viable seeds present in the soil and on its surface. Seedbanks consist of both recent and older seed shed in, and dispersed into a locality. This reserve of propagules is the source of local diversity, and is essential for the continuing existence of the flora in that locality (Jack 1999). The weed seedbank is the principal source of annual weeds in the field crops. Size and composition of the seedbank as well as above ground weed flora reflect the past and present weed, crop, and soil management strategies (Roberts and Neilson 1981). Reducing the size of weed seedbank has been a long-term goal of any weed management strategies, particularly in continuously cultivated fields (Schweizer and Zimdahl 1984). Unless reducing the weed seedbank in the soil the effort made managing the weeds will be a time being process. Keeping these facts in view, an experiment was planned and conducted with an objective to assess the effect of different weed management practices on yield of direct seeded rice and soil seedbank by measuring the weed seedling emergence from the soil collected after the harvest of the dry-DSR.

MATERIALS AND METHODS

The field experiment was conducted during *Kharif*, 2016 and 2017 at the Main Research Station, Hebbal, Bengaluru. The soil type was sandy loam with a pH of 6.8, with organic carbon of 0.55%. The experiment consisted 12 treatments, *viz.* bensulfuron methyl + pretilachlor *fb* triafamone + ethoxysulfuron (RM) (60 + 600 /60 g/ha), oxadiargyl *fb* triafamone + ethoxysulfuron (RM) (100/60 g/ha), pendimethalin *fb* triafamone + ethoxysulfuron (RM) (1000/60 g/ha), pyrazosulfuron-ethyl *fb* triafamone + ethoxysulfuron (RM) (20/60 g/ha), bensulfuron-methyl + pretilachlor *fb* bispyribac-sodium (60 + 600/25 g/ha), oxadiargyl *fb* bispyribac-sodium (100/25 g/ha), pendimethalin* *fb* bispyribac-sodium (1000/25 g/ha), pyrazosulfuron -ethyl *fb* bispyribac-sodium (20/25 g/ha), pendimethalin *fb* penoxsulam + cyhalofop-butyl (RM) (1000 /135 g/ha), three mechanical weedings (20, 40, 60 DAS), hand weedings (20, 40, 60 DAS) and weedy check were tested in a randomized block design with three replications. Rice variety MAS 946 was sown at a inter row spacing of 30 cm and seeds were placed closely. The crop was fertilized with 100 kg N, 50 kg P and 50 kg K/ha. These treatment combinations were replicated thrice in a randomized complete block design (RCBD). The pre-emergence and post–emergence herbicides were applied using spray volume of 750 liters/ha and 500 liters/ha, respectively with Knap-sack sprayer having WFN nozzle. Plants in the net plot area were harvested and threshed separately in each plot and grains were separated, dried under sun and the grain yield per plot was recorded after cleaning. From this yield per plot was computed and converted as ton per hectare.

Species wise weed density (number/m^2) were recorded at rice harvest at two spots per plot. The weeds present were counted categorizing them as sedge, grasses and broad leaf weeds and expressed as number m^{-2} and averaged over two random spots per plot. At 60 days after sowing growth parameters, *viz*., plant height (cm), leaf area (cm^2 per meter row length), total dry weight (g) and at harvest, the data on rice yield, straw yield were collected.

The weed seed distribution at different depths in the soils of the experimental site was studied in pot culture experiments. Soil samples were collected from the experimental site after harvest of dry DSR. The soil samples were taken at two different depths *i.e*., 0-10 and 10-20 cm and dried under shade. One kg of soil from each depth was weighed and kept in the plastic tray containing holes at bottom side in all the four corners and replicated thrice to study the emerged weeds present in the soil. The trays were watered manually as and when needed to maintain adequate moisture. After germination, the weed seedlings were identified, counted and removed and again soil was thoroughly stirred and watered regularly for another flush of weeds. The cycle of operation was repeated till all the weed seeds were exhausted. Data averaged over three replications and two spots per replication after harvesting of paddy crop in both the years. The data collected was statistically analyzed using the standard procedure and the results were tested at five per cent level of significance (Gomez and Gomez 1984). The critical difference was used to compare treatment means.

RESULTS AND DISCUSSION

Weed flora

The major weeds associated with dry direct-seeded rice at harvest during 2016 and 2017 were *Cyperus rotundus* (sedge), *Cynodon dactylon, Chloris barbata, Digitaria marginata, Echinolchloa colona, Eleusine indica* (among grasses) (**Table 1**). Whereas, among broad-leaf weeds, major weeds were *Commelina benghalensis, Alternanthera sessilis, Ageratum conyzoides, Acanthospermum hispida, Emilia sonchifolia, Lagascea mollis, Euphorbia geniculata, Euphorbia hirta, Borreria hispida, Phyllanthus niruri* and *Tridax procumbens*. Predominant category of weed was broad-leaved followed by grasses and sedges. Among the weed species, the densities of *Cyperus rotundus, Cynodon dactylon, Digitaria, marginata, Ageratum conyzoides, Commelina benghalensis* and *Alternanthera sessilis* were more than other weed species. Indicating their dominance and competitiveness with the dry direct-seeded rice (**Table 1**). The emergence of different weed species is mainly attributed to different weed management treatments, initial soil weed seedbank, difference in tillage intensity during land preparation, earlier cropping system, weather parameters during crop growth, favorable soil environment, *etc*. Similar results were observed by Yogananda *et al.* (2017).

Growth parameters and yield

The data pertaining to growth parameters and yield of dry direct-seeded rice were significantly influenced by different weed management practices.is presented in the **Table 2**.

At 60 days after sowing hand weeding at 20, 40 and 60 days after sowing as recorded significantly highest plant height (36.85 cm), leaf area (1096.07 cm^2 per meter row length) and total dry weight (51.41 g) compared to all the treatments and it was found statistically at par with application of bensulfuron-methyl + pretilachlor *fb* bispyribac-

Table 1. Effect of different weed manag ement practices on major weed species' density (no./m^2) in dry direct-seeded rice (pooled data of two years)

Treatment	Sedges		Grasses						Broad-leaf weeds										Total weeds
	Cr	Total	Cd	Da	Dm	Ec	Clb	Total	Alt	Bh	Cv	Cb	Ac	Ah	Spa	Eg	Eh	Total	
Bensulfuron-methyl + pretilachlor *fb* triafamone + ethoxysulfuron	7.0	7.0	5.4	3.7	3.0	2.3	0.0	15.3	7.0	4.4	3.0	0.0	2.0	1.0	0.4	1.7	0.4	22.7	45.0
Oxadiargyl *fb* triafamone + ethoxysulfuron	16.3	16.3	8.7	6.3	8.7	5.7	3.4	34.7	13.7	8.0	7.4	5.7	7.0	1.7	7.7	4.0	2.7	84.4	135.4
Pendimethalin *fb* triafamone + ethoxysulfuron	17.7	17.7	11.0	9.0	10.7	6.7	6.0	45.0	8.4	11.4	8.7	7.4	7.4	7.4	6.0	6.3	2.3	104.4	167.0
Pyrazosulfuron-ethyl *fb* triafamone + ethoxysulfuron	16.7	16.7	9.7	7.4	8.3	8.0	3.3	39.7	10.3	10.7	7.7	8.0	8.7	7.0	6.7	6.0	2.0	89.0	145.4
Bensulfuron-methyl + pretilachlor *fb* bispyribac-sodium	6.4	6.4	6.0	2.0	2.7	1.7	0.7	14.4	6.4	3.0	3.0	1.0	0.7	2.4	1.0	1.0	0.7	20.7	41.4
Oxadiargyl *fb* bispyribac-sodium	11.4	11.4	9.0	4.0	5.7	5.0	2.0	28.7	11.4	7.0	4.0	4.3	7.0	2.0	6.4	2.3	2.0	61.7	101.7
Pendimethalin* *fb* bispyribac-sodium	14.7	14.7	9.7	8.0	7.3	1.3	2.3	29.7	12.0	6.0	4.7	4.3	4.4	1.7	6.0	2.4	0.4	59.3	103.7
Pyrazosulfuron-ethyl *fb* bispyribac-sodium	11.0	11.0	10.0	4.0	3.7	4.3	1.4	25.7	8.7	6.4	2.0	6.7	1.4	3.0	2.4	1.7	3.0	43.0	79.7
Pendimethalin* *fb* penoxsulam + cyhalofop-butyl	20.0	20.0	10.7	10.4	9.0	5.7	2.7	42.4	9.0	14.3	6.7	6.4	6.0	7.3	6.4	4.7	5.0	104.0	166.3
Mechanical weedings	17.7	17.7	8.4	8.4	8.4	7.7	4.0	38.4	11.3	12.0	11.0	8.0	12.0	5.4	4.7	4.3	3.0	106.0	162.0
Hand weedings	5.7	5.7	5.7	2.7	2.3	2.0	0.4	13.0	6.0	3.3	2.0	1.0	1.0	0.0	1.0	0.4	0.4	19.4	38.0
Weedy check	20.4	20.4	12.7	11.0	16.7	8.0	8.7	60.0	8.7	12.0	11.0	10.4	8.7	10.7	8.7	9.0	7.0	130.0	210.3

Data averaged over three replications and two spots per replication; Sedge: Cr- *Cyperus rotundus,* Grasses: Cd-*Cynodon dactylon*, Da – *Dactyolacteium aegptium,* Ec - *Echinochloa colona*, Clb-*Chloris barbata;* Broad-leaf weeds: Alt-*Alternanthera sessilis*, Bh- *Borreria hispida*, Cv-*Cleome viscosa,* Cb - *Commelina benghalensis*, Es-*Emilia sonchifolia*, Eg - *Euphorbia –geniculata,* Lm-*Lagascea mollis*, Sa-*Spilanthes acmella*, Eh-*Euphorbia hirta,* Ah- *Acanthospermum hispida* Pn – *Phyllanthus niruri;* *The Total of grasses and broad leaf weeds includes values of other minor weeds also which are not mentioned in total; *Pendimethalin (38.7% CS), RM: Ready Mix, *fb*: Followed by

Table 2. Effect of different weed management practices in dry direct-seeded rice on growth parameters and yield (pooled data of two years)

Treatment	Plant height (cm)	Leaf area (cm^2 per meter row length)	Total dry weight (g)	Grain yield (t/ha)			Straw yield (t/ha)			Harvest index
				2016	2017	Pooled	2016	2017	Pooled	
Bensulfuron-methyl + pretilachlor *fb* triafamone + ethoxysulfuron	35.89	1068.86	49.39	4.95	5.63	5.29	6.86	7.20	7.03	0.43
Oxadiargyl *fb* triafamone + ethoxysulfuron	30.36	901.89	37.83	4.11	4.68	4.39	6.06	6.21	6.14	0.42
Pendimethalin *fb* triafamone + ethoxysulfuron	28.73	849.96	35.99	3.89	4.42	4.15	6.01	6.16	6.09	0.41
Pyrazosulfuron-ethyl *fb* triafamone + ethoxysulfuron	29.70	883.04	36.78	4.04	4.60	4.32	6.08	6.23	6.15	0.41
Bensulfuron-methyl + pretilachlor *fb* bispyribac-sodium	36.46	1082.29	50.14	5.04	5.73	5.39	7.07	7.25	7.16	0.43
Oxadiargyl *fb* bispyribac sodium	31.63	946.03	44.33	4.15	4.69	4.42	6.04	6.19	6.11	0.42
Pendimethalin *fb* bispyribac sodium	30.60	911.51	41.53	4.16	4.70	4.43	6.04	6.19	6.11	0.42
Pyrazosulfuron ethyl *fb* bispyribac sodium	31.85	947.14	46.58	4.21	4.75	4.48	6.13	6.28	6.20	0.42
Pendimethalin *fb* penoxsulam + cyhalofop-butyl	27.93	830.52	33.15	3.90	4.41	4.15	6.06	6.21	6.13	0.40
Mechanical weedings	30.04	894.27	36.36	4.11	4.64	4.38	6.11	6.26	6.19	0.41
Hand weeding	36.85	1096.07	51.41	5.17	5.84	5.50	7.13	7.31	7.22	0.43
Weedy check	26.29	763.69	29.93	1.31	1.49	1.40	2.29	2.35	2.32	0.38
LSD(p=0.05)	2.79	85.71	3.64	0.59	0.65	0.62	0.96	0.99	0.97	NS

NS- Non-significant; RM: Ready Mix, *fb*: Followed by

sodium, (36.46 cm, 1082.29 cm^2 per meter row length, and 50.14 g, respectively) and bensulfuron-methyl + pretilachlor *fb* triafamone + ethoxysulfuron (35.89 cm, 1068.86 cm^2 per meter row length and 49.39 g, respectively). Among the various weed management treatments hand weeding at 20, 40 and 60 days after sowing as recorded significantly highest grain (5.50 t/ha) and straw yield (7.22 t/ha) compared to all the treatments. But, it was statistically at par with pre-emergence application of bensulfuron-methyl + pretilachlor *fb* bispyribac-sodium, (5.39 and 7.16 t/ha, respectively) and bensulfuron-methyl + pretilachlor *fb* triafamone + ethoxysulfuron (5.29 and 7.03 t/ha, respectively). It is primarily due to effective management of weeds, which lead to enhance the growth and yield parameters of dry direct-seeded rice. These results were found in conformity with Singh *et al.* (2016) and Yogananda *et al.* (2017). Whereas, significantly lowest gain yield (1.40 t/ha) and straw yield (2.32 t/ha) was noticed in weedy check due to sever completion by weeds, which affected the growth, nutrient uptake and yield parameters of the crop drastically.

Table 3. Effect of different weed management practices in dry direct-seeded rice on seedling emergence of different categories of weed seeds in soil collected from 0-10 and 10-20 cm depth (pooled data of two years)

Treatment	Total weed seeds (no./kg of soil)							
	0-10 cm soil depth				10-20 cm soil depth			
	Sedges	Grasses	BLW	Total	Sedges	Grasses	BLW	Total
Bensulfuron methyl + pretilachlor *fb* triafamone + ethoxysulfuron	1.18(0.4)	1.89(2.6)	1.78(2.2)	2.47(5.1)	1.22(0.5)	2.04(3.2)	1.96(2.9)	2.75(6.6)
Oxadiargyl *fb* triafamone + ethoxysulfuron	1.56(1.4)	2.45(5.1)	2.48(5.2)	3.55(11.7)	1.76(2.1)	2.65(6.1)	2.72(6.4)	3.95(14.6)
Pendimethalin *fb* triafamone + ethoxysulfuron	1.71(1.9)	2.49(5.2)	2.84(7.1)	3.90(14.2)	1.87(2.5)	2.79(6.8)	2.98(7.9)	4.27(17.2)
Pyrazosulfuron-ethyl *fb* triafamone + ethoxysulfuron	1.63(1.7)	2.36(4.6)	2.68(6.2)	3.66(12.4)	1.88(2.5)	2.64(6.0)	2.87(7.3)	4.10(15.8)
Bensulfuron-methyl + pretilachlor *fb* bispyribac-sodium	1.15(0.3)	1.78(2.2)	1.65(1.7)	2.28(4.2)	1.20(0.4)	1.99(2.9)	1.90(2.7)	2.65(6.1)
Oxadiargyl *fb* bispyribac-sodium	1.47(1.2)	2.18(3.8)	2.29(4.3)	3.19(9.2)	1.78(2.2)	2.39(4.7)	2.41(4.9)	3.57(11.8)
Pendimethalin* *fb* bispyribac-sodium	1.56(1.4)	2.32(4.4)	2.47(5.1)	3.46(10.9)	1.79(2.2)	2.51(5.3)	2.67(6.2)	3.84(13.7)
Pyrazosulfuron ethyl *fb* bispyribac-sodium	1.47(1.2)	2.20(3.9)	2.21(3.9)	3.15(8.9)	1.73(2.0)	2.40(4.8)	2.38(4.7)	3.53(11.4)
Pendimethalin* *fb* penoxsulam + cyhalofop-butyl	1.77(2.2)	2.65(6.1)	2.95(7.7)	4.12(15.9)	1.92(2.7)	2.97(7.8)	3.09(8.6)	4.48(19.1)
Mechanical weedings	1.73(2.0)	2.45(5.1)	2.68(6.2)	3.77(13.3)	1.88(2.6)	2.75(6.7)	2.81(6.9)	4.13(16.1)
Hand weedings	1.15(0.3)	1.61(1.6)	1.60(1.6)	2.12(3.5)	1.20(0.4)	1.88(2.6)	1.83(2.4)	2.53(5.4)
Weedy check	1.90(2.6)	2.89(7.4)	3.16(9.0)	4.47(19.0)	2.13(3.6)	3.23(9.4)	3.25(9.6)	4.85(22.6)
LSD (p=0.05)	0.14	0.27	0.16	0.22	0.16	0.24	0.18	0.22

Data within the parentheses are original values; Transformed values - # = log $\sqrt{x+2}$, + = square root of $(\sqrt{x+1})$. BLW = Broad -leaved weeds , RM: Ready Mix, *fb*: Followed by

Soil weed seedbank

The hand weeding at 20, 40 and 60 DAS in dry-DSR has resulted in lower number of weeds (0.3, 1.6, 1.6 and 3.5; and 0.4, 2.4, 2.6 and 5.4 number of sedges, grasses, broad-leaved weeds seed and total weeds seed/kg soil, respectively) at 0-10 and 10-20 cm depth of soil. It was statistically at par with PE of bensulfuron-methyl + pretilachlor *fb* bispyribac-sodium (0.3, 2.2, 1.6 and 3.5; and 0.4, 2.6, 2.4 and 5.4 number of sedges, grasses, broad-leaved weeds seed and total weeds seed/kg soil, respectively at 0-10 and 10-20 cm depth of soil). and application bensulfuron-methyl + pretilachlor as PE *fb* triafamone + ethoxysulfuron (0.4, 2.6, 2.2 and 5.1; and 0.5, 3.2, 2.9 and 6.6 number of sedges, grasses, broad-leaved weeds seed and total weeds seed/kg soil, respectively at 0-10 and 10-20 cm depth of soil). The weedy check recorded significantly the highest no. of weeds seeds, 2.6, 7.4, 9.0 and 19.0; 3.6, 9.4, 9.6 and 22.6 number of sedges, grasses, broad-leaved weeds seeds and total weeds seeds/kg soil, respectively at 0-10 cm and 10-20 cm depth **(Table 3)**.

The significant reduction in weed flora during the crop growth stages arrested the vegetative and reproductive emergence of weeds in the soil this reflected on reducing the weed seedbank in the soil to a greater extent. In unweeded control treatment, the uncontrolled growth of weeds in the field lead to increased weed seed production and seed rain in the soil, thus recorded higher number of weeds/kg of soil. Hawaldar (2011) also reported the similar results in maize crop weed seedbank studies.

In this study, the pre-emergence application of bensulfuron-methyl + pretilachlor *fb* bispyribac-sodium recorded higher growth, yield and was found to be the best herbicide combination for effective reduction of weed flora and also weed seedbank in dry direct-seeded rice.

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