Mysore J. Agric. Sci., 56 (2) : 211-219 (2022)

Major Weed Flora and Soil Weed Seed Bank as Influenced by different Weed Management Treatments in Dry Direct-seeded Rice

P. NAGARJUN[1]., G. N. DHANAPAL[2], M. T. SANJAY[3], S. B. YOGANANDA[4] AND R. MUTHURAJU[5]
[1,2,3&4]Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
[5]Department of Agricultural Microbiology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : nagarjunp009@gmail.com

ABSTRACT

A field experiment was conducted during *kharif* 2016 and 2017 at the Main Research Station, Hebbal, Bengaluru to study the effect of different weed management treatments in dry direct-seeded rice (upland condition) on weed density, yield and soil weed seed bank 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). After the harvest of the crop a kilogram of soil (0-10 cm and 10-20 cm depth) was taken in a tray from each plot and observations were recorded on germination of weed seeds and weed seedling emergence at various intervals. 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 germination of weed seeds and weed seedling emergence followed by bensulfuron methyl + pretilachlor and triafamone + ethoxysulfuron. Significantly the highest weed seed germination and seedling emergence was noticed from soil collected from weedy check.

Keywords : Direct-seeded rice, Rice herbicides weed seed bank, Weed seedlings emergence

RICE is one of the diverse crops grown in different agro-ecosystems. Rice production systems are undergoing several changes and one of such changes is shift from transplanted rice to direct seeding. Direct seeding of rice (DSR) is spreading rapidly in Asia particularly in Philippines, Malaysia and Thailand as the farmers seek high productivity and profitability to offset increasing costs and scarcity of farm labour (Pandey & Valesco 2002 and Rao *et al.,* 2017). Traditionally, rice is established by transplanting seedlings in puddled soils, which demands a huge amount of water and labour. The method of direct seeding avoids the transplanting and puddling operations. But the major constraint in the successful cultivation of DSR in tropical countries is heavy infestation of weeds which often results in reduction in grain yield from 50 - 91 per cent (Paradkar *et al*., 1997 and Rao *et al*., 2007).

Soil seed banks are reserves of viable seeds present in the soil and on its surface. Seed banks 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 seed bank is the principal source of annual weeds in the field crops. Size and composition of the seed bank 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 seed bank has been a long-term goal of weed management strategies, especially in continuously cropped fields (Schweizer and Zimdahl, 1984). Hence, an experiment was conducted with an objective to assess the soil seed bank by measuring the weed seedling emergence from the soil collected after the harvest of the dry-DSR.

The Mysore Journal of Agricultural Sciences

Material 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 per cent. The experiment consisted 12 treatments, *viz.,* bensulfuron methyl + pretilachlor *fb* triafamone + ethoxysulfurn (RM) (60 + 600 / 60 g/ha), oxadiargyl *fb* triafamone + ethoxysulfuron (RM) (100/ 60 g/ha), pendimetalin *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 (*Pendimethalin 38.7% CS) 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_2O_5 and 50 kg K_2O ha^{-1}. 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 (Water Flooding Jet) nozzle.

Species wise weed counts (number 0.25 m^{-2}) were recorded at at harvest at two spots per plot. These weeds were categorized as sedge, grasses and broad leaf weeds and expressed as number m^{-2} and averaged over two random spots per plot.

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 direct seeded rice. The soil samples were taken at two different depths *i.e.*, 0-10 and 10-20 cm and dried under shade. One kilogram 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 data pertaining to major weed for in the experimental site is presented in the Table 1 and 2.

The major weed flora observed in the research plots was *Cyperus rotundus* (sedge), *Cynodon dactylon*, *Chloris barbata, Digitaria marginata, Echinolchloa colona, Eleusine indica* (among grasses). 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. The emergence of different weed species is mainly attributed to different weed management treatments, initial soil weed seed bank, difference in tillage intensity during land preparation, earlier cropping system, weather parameters during crop growth,

TABLE 1

Major weed species' density (number m^{-2}) in dry direct seeded rice at harvest during *kharif* 2016 as influenced by different weed management practices

Treatments	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 (RM)	7.3	7.3	6.0	6.0	4.0	3.3	0.0	19.3	8.7	4.7	6.0	0.0	2.0	1.3	0.7	2.7	0.7	32.7	59.3
Oxadiargyl *fb* triafamone + ethoxysulfuron (RM)	19.3	19.3	10.0	7.3	9.3	11.3	6.0	44.0	16.7	8.0	12.0	10.0	12.7	2.0	15.3	7.3	5.3	140.7	204.0
Pendimetalin *fb* triafamone + ethoxysulfuron (RM)	20.7	20.7	14.0	12.7	10.7	10.7	10.0	58.0	10.0	12.0	12.0	12.0	12.7	12.0	11.3	11.3	3.3	162.7	241.3
Pyrazosulfuron ethyl *fb* triafamone + ethoxysulfuron (RM)	18.7	18.7	10.7	12.0	7.3	6.7	3.3	40.0	15.3	17.3	10.0	14.7	14.7	11.3	12.0	10.7	2.7	145.3	204.0
Bensulfuron-methyl + pretilachlor *fb* bispyribac sodium	6.7	6.7	7.3	3.3	4.0	2.0	1.3	18.0	8.7	4.7	5.3	2.0	1.3	2.7	0.7	2.0	1.3	30.0	54.7
Oxadiargyl *fb* bispyribac sodium	12.7	12.7	10.0	6.0	8.7	5.3	2.0	32.0	14.7	9.3	5.3	7.3	14.0	0.0	12.0	3.3	4.0	92.7	137.3
Pendimethalin* *fb* bispyribac sodium	16.0	16.0	10.7	8.0	7.3	1.3	3.3	30.7	12.7	4.7	8.7	7.3	8.0	1.3	10.0	4.7	0.7	81.3	128.0
Pyrazosulfuron ethyl *fb* bispyribac sodium	11.3	11.3	10.0	5.3	6.0	3.3	2.0	26.7	11.3	6.7	2.7	10.7	2.0	0.0	4.7	3.3	4.7	60.7	98.7
Pendimethalin* *fb* penoxsulam + cyhalofop butyl (RM)	23.3	23.3	13.3	12.0	14.0	11.3	5.3	56.0	10.7	17.3	12.0	10.7	10.7	13.3	10.0	9.3	10.0	170.0	249.3
Mechanical weedings	18.7	18.7	12.0	10.7	8.7	8.7	6.7	46.7	11.3	13.3	14.7	14.7	18.0	10.7	9.3	5.3	4.7	163.3	228.7
Hand weedings	6.0	6.0	6.7	4.7	1.3	3.3	0.7	16.7	8.0	3.3	4.0	2.0	0.0	0.0	2.0	0.0	0.0	28.0	50.7
T_{12}: Weedy check	24.0	24.0	14.0	16.0	18.7	12.0	11.3	72.0	13.3	13.3	13.3	14.7	11.3	15.3	14.7	12.7	9.3	187.3	283.3

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.

TABLE 2

Major weed species' density (No. m^{-2}) in dry direct seeded rice at harvest during *kharif* 2017 as influenced by different weed management practices

Treatments	Sedges		Grasses						Broad leaf Weeds										Total weeds
	Cr	Total	Cd	Da	Dm	Clb	Ei	Total	Alt	Cb	Ac	Ah	Spa	Eg	Es	Pn	Eh	Total	
Bensulfuron methyl + pretilachlor *fb* triafamone + ethoxysulfuron (RM)	7.3	7.3	8.0	1.3	4.0	1.3	0.0	16.7	6.7	6.0	0.0	2.0	0.7	0.0	0.0	0.7	0.0	16.0	40.0
Oxadiargyl *fb* triafamone + ethoxysulfuron (RM)	13.3	13.3	9.3	6.0	7.3	0.0	0.7	28.0	11.3	8.7	3.3	3.3	0.7	0.0	0.0	0.7	0.0	32.7	74.0
Pendimetalin *fb* triafamone + ethoxysulfuron (RM)	14.7	14.7	12.0	5.3	12.0	2.7	2.0	40.0	14.0	15.3	15.3	2.0	2.7	1.3	0.7	1.3	1.3	71.3	126.0
Pyrazosulfuron ethyl *fb* triafamone + ethoxysulfuron (RM)	14.7	14.7	10.7	2.7	9.3	8.7	3.3	40.7	6.0	4.7	5.3	3.3	2.7	0.0	1.3	1.3	1.3	34.7	90.0
Bensulfuron-methyl + pretilachlor *fb* bispyribac sodium	7.3	7.3	8.0	0.7	1.3	1.3	0.0	14.7	6.7	2.7	0.7	0.0	2.0	0.7	1.3	0.0	0.0	15.3	37.3
Oxadiargyl *fb* bispyribac sodium	12.0	12.0	9.3	2.0	2.7	5.3	0.0	25.3	9.3	4.7	6.7	0.0	4.0	0.7	0.7	1.3	0.0	36.0	73.3
Pendimethalin* *fb* bispyribac sodium	13.3	13.3	9.3	8.7	7.3	2.0	0.7	30.0	11.3	7.3	0.7	0.7	2.0	0.0	2.0	0.0	0.0	38.0	81.3
Pyrazosulfuron ethyl *fb* bispyribac sodium	10.0	10.0	10.0	2.7	1.3	5.3	0.7	26.0	6.0	7.3	1.3	0.7	6.0	1.3	0.0	0.0	1.3	26.7	62.7
Pendimethalin* *fb* penoxsulam + cyhalofop butyl (RM)	16.7	16.7	10.7	8.7	6.7	2.0	0.0	36.0	12.7	14.0	10.7	3.3	3.3	3.3	2.7	0.0	0.0	66.7	119.3
Mechanical weedings	16.7	16.7	9.3	6.0	8.7	6.7	1.3	35.3	12.7	14.7	9.3	6.0	0.0	0.7	0.0	3.3	1.3	60.0	112.0
Hand weedings	7.3	7.3	7.3	2.0	3.3	0.7	0.0	13.3	8.0	3.3	0.0	2.0	0.0	0.0	0.0	0.7	0.7	14.7	35.3
Weedy check	16.7	16.7	12.0	8.7	14.7	5.3	6.0	52.7	14.0	16.0	10.7	6.0	6.0	3.3	2.7	5.3	4.7	94.0	163.3

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.

favorable soil environment, etc. Similar results were observed by Kumaran *et al.* (2015) and Yogananda *et al*. (2017).

Among different weed management practices hand weeding at 20, 40 and 60 DAS recorded lowest weed species' density of sedges, grasses, broad leaved weeds and total weeds at harvest (6.0, 16.7, 28.0 and 50.7 m^{-2} in 2016 and 7.3, 13.3, 14.7, 35.3 m^{-2} in 2017, respectively). Whereas, among the different herbicide combinations the lowest weed density was observed with application of bensulfuron-methyl + pretilachlor as pre-emergence fb bispyribac sodium, (6.7, 18.0,30.0 and 54.7 m^{-2} in 2016 and 7.3, 14.7, 15.3 and 37.3 m^{-2} in 2017, respectively) followed by bensulfuron methyl + pretilachlor as pre-emergence *fb* triafamone + ethoxysulfuron, (7.3, 19.3, 32.7 and 59.3 m^{-2} in 2016 and 7.3, 16.7, 16.0 and 40.0 m^{-2} in 2017, respectively). These herbicides combinations found on par with hand weeding in 20, 40 and 60 DAS in effectively reducing the weed density. This is mainly due broader spectrum effect of both pre and post emergence herbicide which are highly effective in suppressing the major weed

TABLE 3

Effect of different weed management practices in dry direct-seeded rice on weed density at harvest and yield (pooled data of two years)

Treatments	Weed density(no.m^{-2})				Yield	
	Sedges+	Grasses #	Broad leaved weeds #	Total #	Grain yield (t ha^{-1})	Straw Yield (t ha^{-1})
Bensulfuron methyl + pretilachlor *fb* triafamone + ethoxysulfuron	2.89 (7.3)	1.30 (18.0)	1.41 (24.3)	1.71 (49.7)	5.29	7.03
Oxadiargyl *fb* triafamone + ethoxysulfuron	4.16 (16.3)	1.58 (36.0)	1.95 (86.7)	2.15 (139.0)	4.39	6.14
Pendimetalin *fb* triafamone + ethoxysulfuron	4.32 (17.7)	1.71 (49.0)	2.07 (117.0)	2.27 (183.7)	4.15	6.09
Pyrazosulfuron-ethyl *fb* triafamone + ethoxysulfuron	4.20 (16.7)	1.63 (40.3)	1.96 (90.0)	2.17 (147.0)	4.32	6.15
Bensulfuron-methyl + pretilachlor *fb* bispyribac-sodium	2.82 (7.0)	1.26 (16.3)	1.39 (22.7)	1.68 (46.0)	5.39	7.16
Oxadiargyl *fb* bispyribac sodium	3.65 (12.3)	1.48 (28.7)	1.82 (64.3)	2.03 (105.3)	4.42	6.11
Pendimethalin* *fb* bispyribac sodium	3.95 (14.7)	1.50 (30.3)	1.79 (59.7)	2.03 (104.7)	4.43	6.11
Pyrazosulfuron ethyl *fb* bispyribac sodium	3.41 (10.7)	1.45 (26.3)	1.66 (43.7)	1.92 (80.7)	4.48	6.20
Pendimethalin* *fb* penoxsulam + cyhalofop-butyl	4.58 (20.0)	1.68 (46.0)	2.08 (118.3)	2.27 (184.3)	4.15	6.13
Mechanical weedings	4.32 (17.7)	1.63 (41.0)	2.05 (111.7)	2.23 (170.3)	4.38	6.19
Hand weedings	2.77 (6.7)	1.23 (15.0)	1.37 (21.3)	1.65 (43.0)	5.50	7.22
Weedy check	4.62 (20.3)	1.81 (62.3)	2.15 (140.7)	2.35 (223.3)	1.40	2.32
S.Em±	0.13	0.05	0.07	0.07	0.21	0.33
CD(p=0.05)	0.39	0.14	0.20	0.21	0.62	0.97

Data within the parentheses are original values; Transformed values - # = log (X+2), + = square root of (X+1).

flora. Thus, resulted in obtaining the lower weed dry weight and the findings agree with Hossain and Mondal (2014) and Sandeep Nayak *et al.* (2014).

Weed Density and Yield

Significantly higher weed density was noticed in weedy check 24.0, 72.0, 187.3 and 223.3 number of sedges, grasses, broad leaved weeds and total weeds m^{-2}, at harvest, which attributed to initial deposition of weed seeds in the soil from the previous seasons has led to increased weed seed bank in the soil which is undisturbed for any activity after sowing and also no weed management measure is taken in these plots. These circumstances have led to higher weed density in the weedy check. These findings are in accordance with Dhanapal *et al*. (2018).

TABLE 4

Effect of different weed management practices in dry direct-seeded rice on seedling emergence of different categories of weeds at 7, 14 and 30 days from weed seeds (no./kg of soil) in soil collected from 0-10 cm depth (Pooled data of two years)

Treatment	7 days				14 days				30 days			
	Sedges	Grasses	BLW	Total	Sedges	Grasses	BLW	Total	Sedges	Grasses	BLW	Total
Bensulfuron-methyl + pretilachlor *fb* triafamone+ethoxysulfuron (RM)	1.29 (0.7)	2.11 (3.5)	2.07 (3.3)	2.91 (7.5)	1.29 (0.7)	2.38 (4.7)	2.22 (4.0)	3.21 (9.3)	1.07 (0.2)	1.53 (1.3)	1.53 (1.3)	1.95 (2.8)
Oxadiargyl *fb* triafamone + ethoxysulfuron (RM)	1.78 (2.2)	2.57 (5.7)	2.67 (6.2)	3.87 (14.0)	1.91 (2.7)	2.88 (7.3)	2.78 (6.8)	4.22 (16.8)	1.58 (1.5)	2.47 (5.2)	2.70 (6.3)	3.73 (13.0)
Pendimethalin *fb* triafamone + ethoxysulfuron (RM)	1.91 (2.7)	2.74 (6.5)	3.02 (8.2)	4.28 (17.3)	1.96 (2.8)	2.99 (8.0)	3.07 (8.5)	4.51 (19.3)	1.73 (2.0)	2.61 (5.8)	2.85 (7.2)	4.00 (15.0)
Pyrazosulfuron-ethyl *fb* triafamone + ethoxysulfuron (RM)	1.91 (2.7)	2.58 (5.7)	2.82 (7.0)	4.04 (15.3)	2.00 (3.0)	2.84 (7.2)	3.04 (8.3)	4.41 (18.5)	1.73 (2.0)	2.48 (5.2)	2.74 (6.5)	3.83 (13.7)
Bensulfuron-methyl + pretilachlor *fb* bispyribac-sodium	1.29 (0.7)	2.08 (3.3)	2.02 (3.2)	2.85 (7.2)	1.22 (0.5)	2.27 (4.2)	2.13 (3.7)	3.05 (8.3)	1.07 (0.2)	1.53 (1.3)	1.47 (1.2)	1.91 (2.7)
Oxadiargyl *fb* bispyribac-sodium	1.78 (2.2)	2.27 (4.2)	2.40 (4.8)	3.48 (11.2)	1.87 (2.5)	2.61 (5.8)	2.52 (5.5)	3.85 (13.8)	1.68 (1.8)	2.26 (4.2)	2.30 (4.3)	3.35 (10.3)
Pendimethalin* *fb* bispyribac-sodium	1.78 (2.2)	2.43 (5.0)	2.61 (5.8)	3.74 (13.0)	1.87 (2.5)	2.70 (6.3)	2.80 (7.0)	4.10 (15.8)	1.73 (2.0)	2.38 (4.7)	2.57 (5.7)	3.64 (12.3)
Pyrazosulfuron-ethyl *fb* bispyribac-sodium	1.73 (2.0)	2.27 (4.2)	2.34 (4.5)	3.41 (10.7)	1.77 (2.2)	2.58 (5.7)	2.45 (5.0)	3.72 (12.8)	1.68 (1.8)	2.33 (4.5)	2.34 (4.5)	3.44 (10.8)
Pendimethalin* *fb* penoxsulam + cyhalofop-butyl (RM)	1.95 (2.8)	2.91 (7.5)	3.08 (8.5)	4.45 (18.8)	1.95 (2.8)	3.15 (9.0)	3.13 (8.8)	4.65 (20.7)	1.86 (2.5)	2.83 (7.0)	3.04 (8.3)	4.34 (17.8)
Three mechanical weedings	1.91 (2.7)	2.65 (6.2)	2.77 (6.7)	4.05 (15.5)	1.95 (2.8)	2.92 (7.7)	2.88 (7.3)	4.34 (17.8)	1.78 (2.2)	2.65 (6.2)	2.77 (6.7)	3.99 (15.0)
Hand weedings	1.29 (0.7)	1.94 (2.8)	1.94 (2.8)	2.70 (6.3)	1.22 (0.5)	2.16 (3.7)	2.02 (3.2)	2.88 (7.3)	1.07 (0.2)	1.47 (1.2)	1.47 (1.2)	1.87 (2.5)
Weedy check	2.12 (3.5)	3.07 (8.5)	3.19 (9.2)	4.70 (21.2)	2.12 (3.5)	3.36 (10.3)	3.24 (9.5)	4.93 (23.3)	2.16 (3.7)	3.23 (9.5)	3.31 (10.0)	4.91 (23.2)
S.Em±	0.06	0.09	0.07	0.09	0.05	0.08	0.08	0.08	0.06	0.13	0.09	0.12
CD(p=0.05)	0.19	0.27	0.22	0.25	0.15	0.24	0.24	0.24	0.19	0.38	0.28	0.35

Data within the parentheses are original values; Transformed values - # = log (X+2), + = square root of (X+1).
BLW=Broad leaved weeds
*Pendimethalin (38.7% CS), RM: Ready Mix, *fb*: Followed by Spray volume: 750 L/ha for pre-emergence and 500 L/ha for post-emergence herbicides

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^{-1}) and straw yield (7.22 t ha^{-1}) compared to all the treatments. But, it was statistically at par with pre-emergence application of bensulfuronmethyl + pretilachlor *fb* bispyribac-sodium, (5.39 and 7.16 t ha^{-1}, respectively) and bensulfuron-methyl + pretilachlor *fb* triafamone + ethoxysulfurn (5.29 and 7.03 t ha^{-1}, 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 Yogananda *et al*. (2017). Whereas, significantly lowest gain yield (1.40 t ha^{-1}) and straw yield (2.32 t ha^{-1}) 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 5

Effect of different weed management practices in dry direct-seeded rice on seedling emergence of different categories of weeds at 7, 14 and 30 days from weed seeds (no./kg of soil) in soil collected from 10-20 cm depth (Pooled data of two years)

Treatment	7 days				14 days				30 days			
	Sedges	Grasses	BLW	Total	Sedges	Grasses	BLW	Total	Sedges	Grasses	BLW	Total
Bensulfuron-methyl + pretilachlor *fb* triafamone+ethoxysulfuron (RM)	1.07 (0.2)	1.91 (2.7)	1.82 (2.3)	2.47 (5.2)	1.35 (0.8)	2.16 (3.7)	1.96 (2.8)	2.89 (7.3)	1.07 (0.2)	1.53 (1.3)	1.53 (1.3)	1.95 (2.8)
Oxadiargyl *fb* triafamone + ethoxysulfuron (RM)	1.47 (1.2)	2.38 (4.7)	2.48 (5.2)	3.46 (11.0)	1.73 (2.0)	2.61 (5.8)	2.58 (5.7)	3.80 (13.5)	1.46 (1.2)	2.35 (4.7)	2.38 (4.7)	3.38 (10.5)
Pendimethalin *fb* triafamone + ethoxysulfuron (RM)	1.73 (2.0)	2.55 (5.5)	2.83 (7.0)	3.94 (14.5)	1.91 (2.7)	2.74 (6.5)	2.94 (7.7)	4.22 (16.8)	1.46 (1.2)	2.16 (3.7)	2.73 (6.5)	3.51 (11.3)
Pyrazosulfuron-ethyl *fb* triafamone + ethoxysulfuron (RM)	1.58 (1.5)	2.37 (4.7)	2.64 (6.0)	3.63 (12.2)	1.87 (2.5)	2.45 (5.0)	2.77 (6.7)	3.89 (14.2)	1.41 (1.0)	2.23 (4.0)	2.61 (5.8)	3.44 (10.8)
Bensulfuron-methyl + pretilachlor *fb* bispyribac-sodium	1.07 (0.2)	1.82 (2.3)	1.77 (2.2)	2.37 (4.7)	1.35 (0.8)	2.04 (3.2)	1.78 (2.2)	2.67 (6.2)	1.00 (0.0)	1.41 (1.0)	1.35 (0.8)	1.67 (1.8)
Oxadiargyl *fb* bispyribac-sodium	1.29 (0.7)	2.08 (3.3)	2.19 (3.8)	2.97 (7.8)	1.68 (1.8)	2.38 (4.7)	2.37 (4.7)	3.48 (11.2)	1.41 (1.0)	2.08 (3.3)	2.31 (4.3)	3.11 (8.7)
Pendimethalin* *fb* bispyribac-sodium	1.47 (1.2)	2.26 (4.2)	2.41 (4.8)	3.34 (10.2)	1.78 (2.2)	2.54 (5.5)	2.65 (6.0)	3.83 (13.7)	1.41 (1.0)	2.12 (3.5)	2.34 (4.5)	3.16 (9.0)
Pyrazosulfuron-ethyl *fb* bispyribac-sodium	1.29 (0.7)	2.04 (3.2)	2.11 (3.5)	2.88 (7.3)	1.78 (2.2)	2.33 (4.5)	2.37 (4.7)	3.51 (11.3)	1.29 (0.7)	2.22 (4.0)	2.12 (3.5)	3.03 (8.2)
Pendimethalin* *fb* penoxsulam + cyhalofop-butyl (RM)	1.82 (2.3)	2.77 (6.7)	2.92 (7.5)	4.18 (16.5)	1.95 (2.8)	2.88 (7.3)	3.03 (8.2)	4.40 (18.3)	1.51 (1.3)	2.27 (4.2)	2.91 (7.5)	3.74 (13.0)
Three mechanical weedings	1.68 (1.8)	2.50 (5.3)	2.58 (5.7)	3.71 (12.8)	1.96 (2.8)	2.65 (6.2)	2.77 (6.7)	4.07 (15.7)	1.51 (1.3)	2.17 (3.8)	2.68 (6.2)	3.50 (11.3)
Hand weedings	1.07 (0.2)	1.58 (1.5)	1.68 (1.8)	2.12 (3.5)	1.35 (0.8)	1.91 (2.7)	1.73 (2.0)	2.55 (5.5)	1.00 (0.0)	1.29 (0.7)	1.35 (0.8)	1.58 (1.5)
Weedy check	1.82 (2.3)	2.91 (7.5)	3.00 (8.0)	4.34 (17.8)	2.04 (3.2)	3.00 (8.0)	3.29 (9.8)	4.69 (21.0)	1.82 (2.3)	2.76 (6.7)	3.19 (9.2)	4.37 (18.2)
S.Em±	0.05	0.10	0.08	0.10	0.06	0.10	0.08	0.09	0.09	0.13	0.07	0.13
CD(p=0.05)	0.15	0.28	0.23	0.28	0.16	0.30	0.23	0.27	0.26	0.38	0.20	0.39

Data within the parentheses are original values; Transformed values - # = log (X+2), + = square root of (X+1).
BLW=Broad leaved weeds
*Pendimethalin (38.7% CS), RM: Ready Mix, *fb*: Followed by Spray volume: 750 L/ha for pre-emergence and 500 L/ha for post-emergence herbicides

Soil Weed Seed Bank

Among various weed management practices, at 0-10 cm depth of soil hand weeding at 20, 40 and 60 DAS has showed lower number of weeds (0.7, 2.8, 2.8 and 6.3 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 7 days, 0.5, 3.7, 3.2 and 7.3 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 14 days, 0.2, 1.2, 1.2 and 2.5 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 30 days) and it was found statistically on par with pre-emergence application of bensulfuron-methyl + pretilachlor *fb* bispyribac sodium (0.7, 3.5, 3.3 and 7.5 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 7 days, 0.5, 4.2, 4.0 and 8.3 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 14 days, 0.2, 1.3, 1.2 and 2.7 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 30 days) and application bensulfuron methyl + pretilachlor as pre-emergence *fb* triafamone + ethoxysulfuron (0.7, 3.5, 3.3 and 7.5 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 7 days, 0.7, 4.7, 4.0 and 9.3 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 14 days, 0.2, 1.3, 1.3 and 2.8 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 30 days). Whereas, weedy check recorded significantly highest number of weeds (3.5, 8.5, 9.2 and 21.2 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 7 days, 3.5, 10.3, 9.5 and 23.3 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 14 days, 3.7, 9.5, 10.0 and 23.2 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 30 days) [Table 4].

Among different weed management practices, at 10-20 cm depth of soil hand weeding at 20, 40 and 60 DAS has exhibited lower number of weeds (0.2, 1.5, 1.8 and 3.5 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 7 days, 0.8, 2.7, 2.0 and 5.5 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 14 days, 0.0, 0.7, 0.8 and 1.5 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 30 days) [Table 4]. However, it was statistically on par with pre-emergence application of bensulfuron-methyl + pretilachlor *fb* bispyribac sodium (0.2, 1.7, 2.2 and 4.7 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 7 days,0.8, 3.2, 2.2 and 6.2 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 14 days, 0.0, 1.0, 1.3 and 1.8 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 30 days) and application of bensulfuron methyl + pretilachlor as pre-emergence fb triafamone + ethoxysulfuron (0.2, 2.0, 2.3 and 5.2 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 7 days, 0.8, 3.7, 2.8 and 7.3 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 14 days, 0.2, 1.3, 0.8 and 1.8 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 30 days). Whereas, weedy check recorded significantly highest number of weeds (2.3, 7.5, 8.0 and 17.8 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 7 days, 3.2, 8.0, 9.8 and 21.0 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 14 days, 2.3, 6.7, 9.2 and 18.2 number of sedges, grasses, broad leaved weeds and total weeds kg^{-1} soil, respectively at 30 days).

The significant decrease 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 seed bank in the soil to a greater extent. In unweeded control treatment, the uncontrolled growth of weeds in the field lead to increased weed seed 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 seed bank studies.

From of the study it is revealed that pre-emergence application of bensulfuron-methyl + pretilachlor *fb* bispyribac-sodium and bensulfuron methyl + pretilachlor *fb* triafamone + ethoxysulfuron found to be the best herbicide combination for effective

reduction of weed flora and also weed seed bank in dry direct-seeded rice cultivation.

REFERENCES

DHANAPAL, G. N., SANJAY, M. T., NAGARJUN, P. AND SANDEEP, A., 2018, Integrated weed management for control of complex weed flora in direct-seeded upland rice under southern transition zone of Karnataka. *Indian J. Weed Sci*., **50** (1) : 33 - 36.

GOMEZ, K. A. AND GOMEZ, A. A., 1984, Statistical procedure for agricultural Research. *An International Rice Research Institute Book,* A Willey - Inter Science, John wiley and sons Inc. New York, United states of America.

HAWALDAR, S.. 2011, Effect of herbicides on weed seed bank and productivity of maize (*Zea mays* L.). *M.Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad, Karnataka, India.

HOSSAIN AND MONDAL, D. C., 2014, Weed management by herbicide combinations in transplanted rice. *Indian J. Weed Sci*., **46** (3) : 220 - 223.

JACK, D, 1999, Soil weed seed banks and weed management. *J. Crop Prod*., **2** (1) : 139 - 166.

KUMARAN, S. T., KATHISERAN, P., MURALIARTHANARI, C., CHINNUSAMY AND SANJIVKUMAR, V., 2015, Efficacy of new herbicide (byspyribac sodium 10% SC) against different weed flora, nutrient uptake in rice and their residual effects on succeeding crop of green gram under zero tillage. *J. Appl. Nat. Sci.,* **7** (1) : 279 - 285.

PARADKAR, N. R., KURCHANIA, S. P. AND TIWARI, J. P., 1997, Chemical control of *Parthenium hysterophorus* L. and other associated weeds in upland drilled rice. *Indian J. Weed Sci.,* **29** (3&4) : 151 - 154.

PANDEY, S. AND VELASCO, L., 2002, Economics of direct seeding in Asia : Patterns of adoption and research priorities. Proceedings of the International Workshop on Direct Seeding in Asian Rice Systems : Strategic Issues and Opportunities, 25-28 January 2000, Bangkok, Thailand. Los Banos, (Philippines): International Rice Research Institute, pp. : 383.

RAO, A. N., JOHNSON, D. E., SHIVA PRASAD, B., LADHA, J. K. AND MORTIMER, A. M., 2007, Weed management in direct-seeded rice. *Advn. Agron*., **93** : 155 - 257.

RAO, A. N., BRAINARD, D. C., KUMAR, V., LADHA, J. K. AND JOHNSON, D. E., 2017, Preventive weed management in direct-seeded rice : Targeting the weed seedbank. *Advn. Agron*., **144** : 45 - 142.

ROBERTS, H. A. AND NEILSON, E. J., 1981, Changes in the soil seed bank of four long-term crop / herbicide experiments. *J. Appl. Eco.,* **18** (2) : 661 - 668.

SANDEEP NAYAK, B. N., MUJEEB KHAN, M. D., MOSHA, K. AND PRASUNA RANI, P., 2014, Effect of plant population and weed control treatments on weed population and NPK uptake in direct wet seeded rice sown through drum seeder. *Int. J. Sci. Eng. Res.,* **5** (5) : 2229 - 5518.

SCHWEIZER, E. E. AND ZIMDAHL, R. L., 1984, Weed seed decline in irrigated soil after six years of continuous corn (*Zea mays* L.) and herbicides. *Weed Sci*., **32** : 76 - 83.

YOGANANDA, S. B., THIMMEGOWDA, P. AND SHRUTHI, G. K., 2017, Weed management effect on growth and yield of wet direct-seeded rice in Cauvery command area of Karnataka. *Indian J. Weed Sci.,* **49** (3) : 219 - 222.

(*Received :* September 2021 *Accepted :* April 2022)