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Predominate weed flora in summer rice as influenced by methods of establishment and weed management practices

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ABSTRACT

A field experiment was conducted at the College Farm of Navsari Agricultural University, Navsari (Gujarat), during the summer seasons of 2019-20 and 2020-21. The experiment was arranged in a split-plot design with four replications. Three crop establishment methods were tested in the main plots: S_1 - Direct Seeded Rice, S_2 - Conventional Transplanted Rice, and S_3 - Sprouted Seed (line sowing). Five weed management practices were evaluated in sub-plots within each main plot: W_1 - Weedy check (control), W_2 - Hand weeding twice at 20 and 40 DAS/T, W_3 - Pretilachlor 50% EC 1000 g ai/ha (pre-emergence) followed by Bispyribac sodium 10% SC 25 g ai/ha at 30 DAS/T, W_4 - Pyrazosulfuron-ethyl 10% WP 15 g ai/ha (pre-emergence) followed by Bispyribac sodium 10% SC 25 g ai/ha at 30 DAS/T, and W_5 - Pretilachlor 50% EC 1000 g ai/ha (pre-emergence) followed by Chlorimuron ethyl + Metsulfuron methyl 20% WP 4 g ai/ha at 30 DAS/T. The rice cultivar used was NAUR-1. *Echinochloa colonum* L., *Echinochloa crusgalli* L., *Cynodon dactylon* L., *Eragrostis minor* L., *Digitaria sanguinalis* L., *Dinebra retroflexa (Vahl) Panzer*, *Brachiaria ramose* L. and *Dactyloctenium aegyptium* L. among the grasses; *Cyperus rotundus* L., *Cyperus difformis* L., *Fimbristylis miliacea* L. and *Cyprus iria* L. among the sedges and *Alternanthera sessilis* L., *Marsilea quadrifolia* L., *Commelina benghalensis* L. *Phyllanthus niruri* L., *Euphorbia hirta* L., *Portulaca oleracea* L, *Tridax procumbens* L., *Physalis minima* L. and *Digera arvensis* L. among the broad-leaved weeds, were the major weed species found from the experimental filed during both the seasons of experiment. Among methods of establishment, in direct seeded rice, the grasses weed specie are: *Echinochloa colona* L. and *Echinochloa crus-galli* L., broad leaved weeds are: *Phyllanthus niruri* L. and *Alternanthera sessilis whereas Cyperus rotundus* L and Cyperus *difformis* L. amongst sedge, found dominanat. In conventional transplanted rice, *Echinochloa colona* L., *Digitaria sanguinalis* L. and *Dactyloctenium aegyptium* L. were found dominant during among grasses weeds. Midst broad leaved weeds, *Phyllanthus niruri* L. found relatively superior and in case of sedges, *Cyperus rotundus* L. found superior during both seasons of experiment.

INTRODUCTION

Weed Management is particularly challenging in rice ecosystems due to the diverse and severe weed infestations. This aims to reduce weed populations and growth to minimize their competition with desired plants. Weeds compete with crops for moisture, nutrients, light, space, and other growth factors, emerging early under direct-sown conditions in rice. Without effective control measures, weeds can absorb significant amounts of applied nutrients, leading to substantial yield losses. The type of weeds that establish and compete with a rice crop is heavily influenced by the sowing method, field preparation, and water management practices used. According to Manna (1991), weeds can cause yield reductions of 25% in transplanted rice, 32% in puddle broadcast rice, and 52% in direct-sown upland rice. Under heavy weed infestation, yield reductions of up to 100% have been reported (Rao *et al.*, 2007). Therefore, crop establishment and weed management techniques are crucial in rice farming. This investigation has been conducted with these considerations in mind.

2. Materials and methods

The field experiment was conducted during the summer seasons of 2019-20 and 2020-21 at Navsari Agricultural University, Navsari. The soil of the experimental field was clayey in texture, moderately high in organic carbon, low in available nitrogen, medium in available phosphorus and fairly rich in available potassium. The soil reaction was slightly alkaline with normal electrical conductivity. The trial was laid out in split-plot design and replicated four time. Three crop establishment methods in main plots *viz.* S_1- Direct Seeded Rice, S_2- Conventional Transplanted Rice, S_3- Sprouted Seed (line sowing) and five weed management practices in sub-plots within each main plot *viz.* W_1- Weedy check (control), W_2- 2 HW at 20 and 40 DAS/T, W_3- Pretilachlor 50 % EC 1000 g ai/ha (Pre) fb Bispyribac sodium 10 %

SC 25 g ai/ha at 30 DAS/T, W_4- Pyrazosulfuron-ethyl 10 % WP 15 g ai/ha (Pre) fb Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T and W_5- Pretilachlor 50 % EC 1000 g ai/ha (Pre) fb Chlorimuron ethyl + Metsulfuron methyl 20 % WP 4 g ai/ha at 30 DAS/T. Thus, there were fifteen treatment combinations. rice *Cv.* NAUR-1 was used in the experiment. The crop was fertilized with 120-30 kg NP/ha. The unweeded control plots were considered for studying different weed species infesting the crop. Weeds were categorized into grasses, sedges and broadleaf weeds. On the basis of visual observations, the occurrences of dominant weed species were recorded. For Weed density (No./m^2), Weed was counted from an area enclosed in quadrant of 0.25 square meter randomly selected at two places in each plot at 20 and 40 DAS/T and then averaged and expressed as of meter square. The number of grasses, sedges and broad-leaved weeds falling within the quadrant were counted and recorded. The original weed data were subjected to square root transformation (x + 0.5) on before statistical analysis. For Relative density is the study of numerical strength of a species in relation to the total no. of all the species and can be calculated as per formula proposed by Misra (1968).

$$\text{Relative density (\%)} = \frac{\text{Total no. of individual species}}{\text{Total no. of all weed species}} \times 100$$

3. Result and Discussion

Weed flora: Weed flora such as *Echinochloa colonum* L., *Echinochloa crusgalli* L., *Cynodon dactylon* L., *Eragrostis minor* L., *Digitaria sanguinalis* L., *Dinebra retroflexa* (Vahl) *Panzer, Brachiaria ramose* L. and *Dactyloctenium aegyptium* L. among the grasse, *cyperus rotundus* L., *Cyperus difformis* L., *Fimbristylis miliacea* L. and *Cyprus iria* L. among the sedges and *Alternanthera sessilis* L., *Marsilea quadrifolia* L., *Commelina benghalensis* L. *Phyllanthus niruri* L., *Euphorbia hirta* L., *Portulaca oleracea* L, *Tridax procumbens* L., *Physalis minima* L. and *Digera arvensis* L. among the broad-leaved weeds, were found from the experimental plot. Among them, *Echinochloa colona* L., *Echinochloa crusgalli* L. and *Brachiaria ramose* L. from grasses; *Alternanthera sessilis* L. and *Phyllanthus niruri* L. among broad leaved weeds and *Cyperus rotundus* L. and *Cyperus difformis* L. were found to be the dominant weeds in puddled as well as un-puddled situations because they can tolerate and flourish easily under submerged conditions as that of paddy. Subbulakshmi and Pandian (2002) also reported similar weed flora under puddled condition, however Rekha *et al*. (2002) in transplanted rice and in direct seeded rice; Parameshwari and Srinivas (2014) also reported the dominancy of grasses followed by BLWs and sedges from their study conducted in Rajendranagar, Hyderabad, Telangana.

Table 1: Major weed flora observed during the crop growth period

Sr.no.	Scientific name	English name	Local name	Family	Habitat
(A) Grasses					
1.	*Echinochloa colona* L.	Wild rice	Samo	Poaceae	Annual grass
2.	*Echinochloa crus-galli* L.	Barnyard grass	Bantiyo	Poaceae	Annual grass
3.	*Cynodon dactylon*	Bermuda grass	Dharo	Poaceae	Perennial grass
4.	*Eragostis minor* L.	Love grass	Bhumsi	Poaceae	Annual grass
5.	*Digitaria sanguinalsis* L.	Hairy crabgrass	Arotaro	Poaceae	Annual grass
6.	*Dinebra retroflexa* (Vahl) *Panzer* L.	Viper grass	Khario	Poaceae	Annual grass
7.	*Brachiaria ramose* L.	Signal grass	Bharbhi	Poaceae	Perennial grass
8.	*Dactylotenium aegyptium* L.	Crow foot grass	Makra	Poaceae	Annual/ perennial grass
(B) Broad leaves weeds					
1.	*Alternanthera sessilis* L.	Alligator weed	Khakhi	Amaranthaceae	Annual/ Perennial herb
2.	*Marsilia quadrifolia* L.	Water clover	Veli	Marsileaceae	Perennial fern
3.	*Phyllanthus niruri* L.	Gale of the wind	Bhoyamli	Phyllanthaceae	Annual herb
4.	*Euphorbia hirta* L.	Milk weed	Dudheli	Euphorbiaceae	Annual herb
5.	*Portulaca oleracea* L.	Common purslane	Luni	Portulacaceae	Annual herb
6.	*Commelina benghalensis* L.	Wandering jaw	Sheshmuli	Commelinaceae	Perennial herb
7.	*Tridex procumbens* L.	Tridax daisy	Ekdandi	Asteraceae	Annual /Perennial herb
8.	*Physalis minima* L.	Ground cherry	Popti	Solanaceae	Perennial herb
9.	*Digera arvensis* L.	Digera kondra	Kanjaro	Amaranthaceae	Annual herb
(C) Sedges					
1.	*Cyperus rotundus* L.	Purple nut sedge	Chidho	Cyperaceae	Perennial herb
2.	*Cyperus difformis* L.	Umbrella sedge	Chidho	Cyperaceae	Annual herb
3.	*Cyprus iria* L.	Flat sedge	Chidho	Cyperaceae	Annual herb
4.	*Fimbristylis miliacea* L.	Globefingerush	Fimbristylish	Cyperaceae	Annual/ Perennial herb

Relative weed density: Both the *Echinochloa* spp. were the most dominant weed throughout the crop growth in weedy check under all the rice establishment methods during both the years, however *Echinochloa colona* L., *Echinochloa crusgalli* L., *Brachiaria ramose* L. and *Alternanthera sessilis* L. were the major weeds in direct seeded rice (DSR-dry seeded) at all the growth stages. At 20-day stage, *Physalis minima* during season 1 and *Cyperus difformis* during season 2 were absent but it was a new weed showed their presence at 40 DAS/T and onwards. Alike weed flora was also reported by Mukherjee and Singh (2004) in transplanted rice, whereas, parallel weed flora in direct seeded rice and in aerobic rice was reported by Parameshwari *et al*. (2014) from results of their study conducted in Rajendranagar, Hyderabad, Telangana.

Table 2: Dominant weed flora recorded from weedy check at 20 DAS in Direct Seeded and Transplanted rice

Sr.	Scientific name	Direct Seeded Rice	Transplanted rice

no.		Weed density (no./m^2)		Relative weed density (%)		Weed density (no./m^2)		Relative weed density (%)	
		2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
(A)	**Grasses**								
1.	*Echinochloa colona* L.	9	6	13.04	8.33	8	5	16.67	9.80
2.	*Echinochloa crus-galli* L.	4	11	5.80	15.28	3	4	6.25	7.84
3.	*Cynodon dactylon* L.	2	3	2.90	4.17	5	1	10.42	1.96
4.	*Eragostis minor* L.	7	4	10.14	5.56	4	7	8.33	13.73
5.	*Digitaria saguinalis* L.	5	2	7.25	2.78	1	2	2.08	3.92
6.	*Dinebra retroflexa* (Vahl) *Panzer*	2	4	2.90	5.56	6	4	12.50	7.84
7.	*Brachiaria ramose* L.	8	7	11.59	9.72	2	7	4.17	13.73
8.	*Dactylotenium aegyptium* L.	3	6	4.35	8.33	-	-	-	-
	Total grasses weeds	**40**	**43**	**57.97**	**59.72**	**29**	**30**	**60.42**	**58.82**
(B)	**Broad leaves weeds**								
1.	*Alternanthera sessilis* L.	3	5	4.35	6.94	3	2	6.25	3.92
2.	*Marsilia quadrifolia* L.	2	1	2.90	1.39	1	4	2.08	7.84
3.	*Phyllanthus niruri* L.	5	3	7.25	4.17	5	2	10.42	3.92
4.	*Euphorbia hirta* L.	2	1	2.90	1.39	-	-	-	-
5.	*Portulaca oleracea* L.	2	2	2.90	2.78	4	3	8.33	5.88
6.	*Commelina benghalensis* L.	4	2	5.80	2.78	-	1	-	1.96
7.	*Tridex procumbens* L.	1	3	1.45	4.17	-	-	-	
8.	*Physalis minima* L.	-	2	-	1.39	-	2	-	3.92
9.	*Digera arvensis* L.	2	1	2.90	1.39	2	1	4.17	1.96
Total broad leaves weeds		**21**	**20**	**30.44**	**27.78**	**15**	**15**	**31.25**	**29.42**
(C)	**Sedges**								
1.	*Cyperus rotundus* L.	3	5	4.35	6.94	2	2	4.17	3.92
2.	*Cyperus difformis* L.	1	-	1.45	-	-	1	-	1.96
3.	*Cyprus iria* L.	2	3	2.90	4.17	1	1	2.08	1.96
4.	*Fimbristylis miliacea* L.	2	1	2.90	1.39	1	2	2.08	3.92
	Total sedges weeds	**8**	**9**	**11.59**	**12.5**	**4**	**6**	**8.33**	**11.76**
Total weeds (Grasses, BLW's and sedge)		**69**	**72**	**100**	**100**	**48**	**51**	**100**	**100**

Table 3: Dominant weed flora recorded from weedy check at 40 DAS in Direct Seeded and Transplanted rice

Sr. no.	Scientific name	Direct Seeded Rice				Transplanted rice			
		Weed density (no./m^2)		Relative weed density (%)		Weed density (no./m^2)		Relative weed density (%)	
		2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
(D)	**Grasses**								
1.	*Echinochloa colona* L.	21	19	17.36	15.20	26	22	28.26	22.22
2.	*Echinochloa crus-galli* L.	14	12	11.57	9.60	5	8	5.43	8.08
3.	*Cynodon dactylon* L.	6	7	4.96	5.60	12	9	13.04	9.09
4.	*Eragostis minor* L.	11	13	9.09	10.40	-	-	-	-
5.	*Digitaria saguinalis* L.	1	4	0.83	3.20	8	5	8.70	5.05
6.	*Dinebra retroflexa* (Vahl) *Panzer*	5	8	4.13	6.40	11	8	11.96	8.08
7.	*Brachiaria ramose* L.	18	11	14.88	8.80	2	13	2.17	13.13
8.	*Dactylotenium aegyptium* L.	3	6	2.48	4.80	4	6	4.35	6.06
	Total grasses weeds	**79**	**80**	**65.29**	**64.00**	**68**	**71**	**73.91**	**71.72**
(E)	**Broad leaves weeds**								
1.	*Alternanthera sessilis* L.	11	14	9.09	11.20	2	3	2.17	3.03
2.	*Marsilia quadrifolia* L.	6	3	4.96	2.40	5	2	5.43	2.02
3.	*Phyllanthus niruri* L.	2	1	1.65	0.80	2	8	2.17	8.08
4.	*Euphorbia hirta* L.	1	2	0.83	1.60	-	-	-	-
5.	*Portulaca oleracea* L.	3	2	2.48	1.60	3	1	3.26	1.01
6.	*Commelina benghalensis* L.	2	3	1.65	2.40	1	3	1.09	3.03
7.	*Tridex procumbens* L.	2	1	1.65	0.80	-	-	-	-
8.	*Physalis minima* L.	1	2	0.83	1.60	2	1	2.17	1.01
9.	*Digera arvensis* L.	2	4	1.65	3.20	2	4	2.17	4.04
Total broad leaves weeds		**30**	**32**	**24.79**	**25.60**	**17**	**22**	**18.48**	**22.22**
(F)	**Sedges**								
1.	*Cyperus rotundus* L.	5	4	4.13	3.20	4	2	4.35	2.02

2.	*Cyperus difformis* L.	3	6	2.48	4.80	-	1	-	1.01
3.	*Cyprus iria* L.	1	2	0.83	1.60	1	2	1.09	2.02
4.	*Fimbristylis miliacea* L.	3	1	2.48	0.80	2	1	2.17	1.01
Total sedges weeds		**12**	**13**	**9.92**	**10.40**	**7**	**6**	**7.61**	**6.06**
Total weeds (Grasses, BLW's and sedge)		**121**	**125**	**100**	**100**	**92**	**99**	**100**	**100**

Grasses density: Among the rice establishment methods, conventional transplanted rice (S_2) recorded significantly the lowest density of grasses at 20 DAS/T (17.00, 16.60 and 16.80 no./m^2, respectively) and at 40 DAS/T (18.40, 19.10 and 18.75 no./m^2, respectively) as compared to sprouted seeded rice (S_3) and direct seeded rice (S_1) that recorded significantly higher density of grasses during both the years and in pooled data. Among different weed management practices, distinctly lower grasses density (9.17, 9.00, and 9.08/m^2 at 20 DAS and 3.83, 4.83 and 4.33/m^2 at 40 DAS in the year of 1 and 2 and in pooled, respectively) was recorded with Pretilachlor 50 % EC 1000 g ai/ha (Pre) *fb* Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T (W_3), which was significantly followed by Pyrazosulfuron-ethyl 10 % WP 15 g ai/ha (Pre) *fb* Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T (W_4) and Pretilachlor 50 % EC 1000 g ai/ha (Pre) *fb* Chlorimuron ethyl + Metsulfuron-methyl 20 % WP 4 g ai/ha at 30 DAS/T (W_5). The highest density of grasses (36.33, 40.08, and 38.21/m^2 at 20 DAS and 81.83, 76.92 and 79.38/m^2 at 40 DAS in year 1, year 2 and pooled, respectively) was noticed in weedy check (W_1) at all the stages. The interaction between establishment methods and weed management practices was found to be significant at 20 DAS/T. The significantly lower weed density was found with Pretilachlor 50 % EC 1000 g ai/ha (Pre) *fb* Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T in conventional transplanting at 20 DAS (S_2W_3: 8.25, 7.50 and 7.88 weeds/m^2 in season 1, 2 and pooled, respectively) which was found at par with S_2W_4 and S_2W_5 on pooled basis. The lowest total density of weeds was recorded under conventional transplanting might be due to covering up of seeds with puddled soil into layer deep enough to prevent its emergence above the soil surface. Further, profuse growth of crop in nursery had healthy seedling that cause lower crop-weed competition for solar radiation, space and plant nutrients, which were more available to crop under conventional transplanting which leads to lower weed density in transplanted rice as compared to direct seeded rice. Results are in conformity with Singh *et al*. (2005), Baloch *et al*. (2006), Tadepalli and Singh (2017), Kumar *et al*. (2017) and Jehangir *et al*. (2021).

Table 4: Grasses density at 20 and 40 DAS/T as influenced by methods of establishment and weed management in rice

Treatment	Grasses density/m^2					
	20 DAS/T			40 DAS/T		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Main Plot: Methods of Establishment (S)						
S_1: Direct Seeded Rice	4.56 (23.00)	4.71 (24.75)	4.63 (23.88)	4.00 (23.05)	4.05 (21.95)	4.03 (22.50)
S_2: Conventional Transplanted Rice	**4.02 (17.00)**	**3.95 (16.60)**	**3.98 (16.80)**	**3.47 (18.40)**	**3.68 (19.10)**	**3.57 (18.75)**
S_3: Sprouted Seeds (Line sowing)	4.40 (20.90)	4.54 (22.65)	4.47 (21.78)	4.03 (22.70)	3.95 (21.90)	3.99 (22.30)
SEm ±	0.09	0.12	0.09	0.11	0.09	0.07
C.D. (P=0.05)	0.32	0.42	0.26	0.37	0.32	0.21
CV (%)	9.63	12.28	12.47	12.43	9.85	11.19
Sub Plot: Weed Management (W)						
W_1: Weedy check (Control)	6.04 (36.33)	6.35 (40.08)	6.19 (38.21)	9.06 (81.83)	8.79 (76.92)	8.93 (79.38)
W_2: 2 HW at 20-25 and 40-45 DAS/T	5.95 (35.25)	6.12 (37.58)	6.04 (36.42)	3.36 (10.92)	3.50 (11.92)	3.43 (11.42)
W_3: Pretilachlor 50 % EC 1000 g ai/ha (Pre) *fb* Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T	**3.09 (9.17)**	**3.07 (9.00)**	**3.08 (9.08)**	**2.00 (3.83)**	**2.29 (4.83)**	**2.14 (4.33)**
W_4: Pyrazosulfuron-ethyl 10 % WP 15 g ai/ha (Pre) *fb* Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T	3.26 (10.25)	3.36 (10.92)	3.31 (10.58)	2.31 (5.17)	2.35 (5.08)	2.33 (5.13)
W_5: Pretilachlor 50 % EC 1000 g ai/ha (Pre) *fb* Chlorimuron ethyl + Metsulfuron-methyl 20 % WP 4 g ai/ha at 30 DAS/T	3.30 (10.50)	3.09 (9.08)	3.19 (9.79)	2.44 (5.17)	2.55 (6.17)	2.49 (5.67)
SEm ±	0.09	0.08	0.11	0.13	0.10	0.07
C.D. (P=0.05)	0.27	0.24	0.32	0.38	0.28	0.34
Interactions						
(S × W)	S	S	S	NS	NS	NS
Other interaction (if any)	NS	NS	NS	NS	NS	NS
CV (%)	8.02	7.37	7.69	12.12	8.68	10.52

Figure in parenthesis refers to original value and outside the parenthesis indicates transformed (√X+0.5) value

Table 5: Interaction effect of different methods of rice establishment and weed management on grasses density/m^2 at 20 DAS/T

Grasses density/m^2									
Weed Management (W)	**Methods of Establishment (S)**								
	2019-20			**2020-21**			**Pooled**		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
W_1	6.65 (43.75)	5.34 (28.25)	6.12 (37.00)	6.84 (46.25)	5.63 (31.25)	6.59 (43.00)	6.73 (44.88)	5.49 (29.75)	6.35 (40.00)

W_2	6.40 (40.50)	5.36 (28.50)	6.10 (36.75)	6.84 (46.25)	5.21 (26.75)	6.34 (39.75)	6.60 (43.38)	5.29 (27.63)	6.22 (38.25)
W_3	3.14 (9.50)	**2.93 (8.25)**	3.19 (9.75)	3.19 (9.75)	**2.82 (7.50)**	3.19 (9.75)	3.16 (9.63)	**2.88 (7.88)**	3.19 (9.75)
W_4	3.41 (11.25)	2.99 (8.50)	3.38 (11.00)	3.49 (11.75)	3.11 (9.25)	3.49 (11.75)	3.45 (11.50)	3.05 (8.88)	3.43 (11.38)
W_5	3.22 (10.00)	3.45 (11.50)	3.22 (10.00)	3.23 (10.00)	2.95 (8.25)	3.08 (9.00)	3.22 (10.00)	3.20 (9.88)	3.15 (9.50)
SEm ±	0.10			0.09			0.11		
C.D. (P=0.05)	0.29			0.27			0.32		
CV (%)	8.02			7.37			7.69		

Figure in parenthesis refers to original value and outside the parenthesis indicates transformed (√X+0.5) value

Broad leaved weed density: The study revealed that the transplanting method had recorded significantly minimum broad-leaved weeds density (6.60, 7.70 and 7.15 at 20 DAS/T and 7.60, 7.45 and 7.53/m^2 at 40 DAS/T in year 1, year 2 and pooled, respectively), while direct seeded rice (10.15, 11.35 and 10.75 at 20 DAS and 9.90, 10.10 and 10.00/m^2 at 40 DAS in year 1, year 2 and pooled, respectively) recorded maximum broad-leaved weeds. As usual, transplanted rice get special advantages due to puddling operation, besides healthy seedling of rice had more competitiveness that was reflected in broad leaves weeds population. Among the herbicides, Pyrazosulfuron-ethyl 10 % WP 15 g ai/ha (W_4) recorded significantly lesser density of BLW's at 20 and 40 DAS/T as compared to Pretilachlor 50 % EC 1000 g ai/ha (W_3 and W_4) because of application of Pyrazosulfuron-methyl is a sulfonylurea selective systemic herbicide with a good control effect on broad-leaf weeds and some sedges in rice fields. These results were also in conformity with the work of Baloch *et al.* (2006) and Mandal *et al.* (2013). The interaction effect of establishment methods and weed management practices was significant with respect to broad leaved weed density at 20 DAS/T during individual years and in pooled, whereas at 40 DAS/T on pooled basis only. Significantly lower broad-leaved weed density was observed under conventional transplanting combined with *either* Pyrazosulfuron-ethyl 10 % WP 15 g ai/ha (Pre) *fb* Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T (S_2W_4) *or* Pretilachlor 50 % EC 1000 g ai/ha (Pre) *fb* Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T (S_2W_3) during 1st year and in pooled data. Further, different establishment methods and weed management combinations *i.e.*, S_2W_4, S_2W_3, S_2W_5, S_1W_3, S_1W_4, S_1W_5, S_3W_3, S_3W_4 and S_3W_5 were found equally effective and significantly reduced the broad-leaved weeds compared to rest of the combinations during second year only.

Table 6: Broad leaved weeds density at 20 and 40 DAS/T as influenced by methods of establishment and weed management in rice

Treatment	Broad leaved weed density/m^2					
	20 DAS/T			40 DAS/T		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Main Plot: Methods of Establishment (S)						
S_1: Direct Seeded Rice	2.92 (10.15)	3.13 (11.35)	3.03 (10.75)	2.89 (9.90)	2.92 (10.10)	2.90 (10.00)
S_2: Conventional Transplanted Rice	**2.42 (6.60)**	**2.70 (7.70)**	**2.56 (7.15)**	**2.62 (7.60)**	**2.57 (7.45)**	**2.60 (7.53)**
S_3: Sprouted Seeds (Line sowing)	2.87 (9.55)	2.92 (9.60)	2.90 (9.58)	2.83 (9.40)	2.91 (10.00)	2.87 (9.70)
SEm ±	0.11	0.06	0.06	0.06	0.08	0.05
C.D. (P=0.05)	0.38	0.22	0.20	0.20	0.27	0.15
CV (%)	12.15	9.59	14.25	13.37	12.45	11.83
Sub Plot: Weed Management (W)						
W_1: Weedy check (Control)	4.35 (18.58)	4.45 (19.58)	4.40 (19.08)	5.31 (28.00)	5.41 (29.00)	5.36 (28.50)
W_2: 2 HW at 20-25 and 40-45 DAS/T	4.25 (17.92)	4.29 (18.17)	4.27 (18.04)	2.44 (5.58)	2.34 (5.08)	2.39 (5.33)
W_3: Pretilachlor 50 % EC 1000 g ai/ha (Pre) *fb* Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T	1.67 (2.33)	1.97 (3.42)	1.82 (2.88)	2.14 (4.08)	2.17 (4.25)	2.15 (4.17)
W_4: Pyrazosulfuron-ethyl 10 % WP 15 g ai/ha (Pre) *fb* Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T	**1.63 (2.25)**	**1.90 (3.17)**	**1.76 (2.71)**	**1.92 (3.25)**	**2.02 (3.75)**	**1.97 (3.50)**
W_5: Pretilachlor 50 % EC 1000 g ai/ha (Pre) *fb* Chlorimuron ethyl + Metsulfuron-methyl 20 % WP 4 g ai/ha at 30 DAS/T	1.77 (2.75)	1.97 (3.42)	1.87 (3.08)	2.09 (3.92)	2.07 (3.83)	2.08 (3.88)
SEm ±	0.08	0.07	0.05	0.10	0.09	0.06
C.D. (P=0.05)	0.23	0.21	0.13	0.28	0.27	0.18
Interactions						
(S × W)	S	S	S	NS	NS	S
Other interactions (if any)	NS	NS	NS	NS	NS	NS
CV (%)	10.04	8.50	9.26	12.11	11.54	11.03

Figure in parenthesis refers to original value and outside the parenthesis indicates transformed (√X+0.5) value

Table 7: Interaction effect of different methods of rice establishment and weed management on broad leaved weeds density/m^2 at 40 DAS/T

Weed Management (W)	Broad leaved weeds density/m^2		
	Methods of Establishment (S)		
	Pooled		
	S_1	S_2	S_3
W_1	5.73 (32.38)	4.77 (22.38)	5.59 (30.75)
W_2	2.49 (5.75)	2.25 (4.63)	2.43 (5.63)
W_3	2.14 (4.13)	2.08 (3.88)	2.23 (4.50)
W_4	2.10 (4.00)	**1.85 (3.00)**	1.96 (3.50)
W_5	2.06 (3.75)	2.04 (3.75)	2.14 (4.13)
SEm ±		0.06	
C.D. (P=0.05)		0.18	
CV (%)		11.03	

Figure in parenthesis refers to original value and outside the parenthesis indicates transformed (√X+0.5) value

Sedges density: Among the establishment methods, conventional transplanted rice (S_2) recorded significantly lowest sedges density (3.10, 3.85 and 3.48/m^2 at 20 DAS/T and 3.65, 3.45 and 3.55/m^2 at 40 DAS/T in season 1, 2 and pooled analysis, respectively) as compared to direct seeded rice (S_1: 5.65, 5.00, 5.33 and 5.85, 5.75, 5.80/m^2 at 20 and 40 DAS/T during 2020, 2021 and in pooled analysis, respectively) and sprouted seed line sowing (S_3: 5.05, 4.90 and 4.98 and 5.80, 5.60 and 5.70/m^2 at 20 and 40 DAS/T, respectively during 2020, 2021 and in pooled analysis, respectively) which recorded significantly higher sedges density. Among different weed management practices, distinctly lower sedge density (3.17, 3.19, 3.18 and 3.00, 2.67, 2.83/m^2 at 20 and 40 DAS/T in year 1, 2 and pooled, respectively) was observed with application of Pretilachlor 50 % EC 1000 g ai/ha (Pre) *fb* Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T (W_3) which was significantly superior over 2 HW at 20-25 and 40-45 DAS/T (W_2: 6.42, 4.83, 5.63 and 5.67, 4.92, 5.29/m^2 at 20 and 40 DAS/T during year 1, 2 and pooled analysis, respectively). Further, combination of pre and post emergence herbicide provide better weed control for long period of time as reported by Joshi *et al*. (2015), Chadachanakar *et al*. (2017) and Bhatt *et al*. (2017). The interaction was found to be significant between different establishment methods and weed management practices in pooled analysis at 20 DAS/T. The lowest sedge density (2.50/m^2) was observed with Pretilachlor 50 % EC 1000 g ai/ha (Pre) *fb* Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T with conventional transplanting (S_2W_3), which was found significantly similar to S_2W_4 *i.e.*, conventional transplanting with Pyrazosulfuron-ethyl 10 % WP 15 g ai/ha (Pre) *fb* Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T (3.25/m^2) and S_2W_5 *i.e.*, conventional transplanting with Pretilachlor 50 % EC 1000 g ai/ha (Pre) *fb* Chlorimuron ethyl + Metsulfuron-methyl 20 % WP 4 g ai/ha at 30 DAS/T (3.13/m^2). However, direct seeded rice under weedy check (S_1W_1) recorded highest weed density (8.63/m^2) which was at par with S_3W_1 *i.e.*, sprouted seed rice under weedy check (8.00/m^2). Such outcome could be detected because conventional transplanting puddling operation limits the growth of weeds, besides pre-emergence application of Pretilachlor and Pyrazosulfuron-ethyl limit the growth of annual sedges.

Table 8: Sedges density/m^2 at 20 and 40 DAS/T as influenced by methods of establishment and weed management in rice

Treatment	Sedges density/m^2					
	20 DAS/T			40 DAS/T		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Main Plot: Methods of Establishment (S)						
S_1: Direct Seeded Rice	2.43 (5.65)	2.29 (5.00)	2.36 (5.33)	2.41 (5.85)	2.38 (5.75)	2.39 (5.80)
S_2: Conventional Transplanted Rice	**1.87 (3.10)**	**2.06 (3.85)**	**1.96 (3.48)**	**1.99 (3.65)**	**1.94 (3.45)**	**1.96 (3.55)**
S_3: Sprouted Seeds (Line sowing)	2.32 (5.05)	2.29 (4.90)	2.30 (4.98)	2.42 (5.80)	2.35 (5.60)	2.38 (5.70)
SEm ±	0.07	0.06	0.04	0.08	0.08	0.06
C.D. (P=0.05)	0.24	0.19	0.14	0.28	0.29	0.18
CV (%)	14.34	11.15	12.84	13.20	12.79	11.07
Sub Plot: Weed Management (W)						
W_1: Weedy check (Control)	2.56 (6.25)	2.85 (7.75)	2.70 (7.00)	3.17 (9.92)	3.28 (10.75)	3.22 (10.33)
W_2: 2 HW at 20-25 and 40-45 DAS/T	2.59 (6.42)	2.29 (4.83)	2.44 (5.63)	2.43 (5.67)	2.30 (4.92)	2.37 (5.29)
W_3: Pretilachlor 50 % EC 1000 g ai/ha (Pre) *fb* Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T	**1.89 (3.17)**	**1.91 (3.19)**	**1.90 (3.18)**	**1.84 (3.00)**	**1.75 (2.67)**	**1.80 (2.83)**
W_4: Pyrazosulfuron-ethyl 10 % WP 15 g ai/ha (Pre) *fb* Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T	2.08 (3.83)	1.96 (3.42)	2.02 (3.63)	2.02 (3.75)	1.95 (3.42)	1.99 (3.58)
W_5: Pretilachlor 50 % EC 1000 g ai/ha (Pre) *fb* Chlorimuron ethyl + Metsulfuron-methyl 20 % WP 4 g ai/ha at 30 DAS/T	1.92 (3.33)	2.05 (3.75)	1.98 (3.54)	1.90 (3.17)	1.83 (2.94)	1.86 (3.04)
SEm ±	0.08	0.07	0.07	0.13	0.11	0.07
C.D. (P=0.05)	0.23	0.20	0.21	0.36	0.31	0.22
Interactions						

(S × W)	NS	NS	S	NS	NS	NS
Other interactions (if any)	NS	NS	NS	NS	NS	NS
CV (%)	12.45	10.79	11.65	12.65	10.23	10.31

Figure in parenthesis refers to original value and outside the parenthesis indicates transformed (√X+0.5) value

Table 9: Interaction effect of different methods of rice establishment and weed management on sedges density/m^2 at 20 DAS/T

Weed Management (W)	Sedges density/m^2		
	Methods of Establishment (S)		
	Pooled		
	S_1	S_2	S_3
W_1	3.02 (8.63)	2.19 (4.38)	2.90 (8.00)
W_2	2.71 (7.00)	2.14 (4.13)	2.48 (5.75)
W_3	2.00 (3.50)	**1.71 (2.50)**	1.99 (3.50)
W_4	2.05 (3.75)	1.92 (3.25)	2.09 (3.88)
W_5	2.04 (3.75)	1.87 (3.13)	2.04 (3.75)
SEm ±		0.07	
C.D. (P=0.05)		0.21	
CV (%)		11.65	

Figure in parenthesis refers to original value and outside the parenthesis indicates transformed (√X+0.5) value

CONCLUSION

In the view of results obtained from the present investigation, it can be concluded that the Direct seeded rice (S_1) among establishment methods and Weedy check (W_1) among weed management treatment recorded profuse weed growth and eventually recorded higher grasses density, broad leaved weed density and sedges density throughout the experiment. Significant lower values of grasses, broad leaved weeds and sedges along with relative weed density was observed with transplanted rice (S_2). Further, among weed management practices, HW at 20-25 and 40-50 DAS/T (W_2) treatment application of Pretilachlor 50 % EC 1000 g ai/ha (PRE) *fb* Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T (W_3), being statistical equal with Pyrazosulfuron-ethyl 10 % WP 15 g ai/ha (PRE) *fb* Bispyribac sodium 10 % SC 25 g ai/ha at 30 DAS/T (W_4) and Pretilachlor 50 % EC 1000 g ai/ha (pre) *fb* Chlorimuron ethyl + Metsulfuron-methyl 20 % WP 4 g ai/ha at 30 DAS/T (W_5) gave lower grasses density, broad leaved weed density and sedges density along with relative weed density.

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