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Weed composition and weed seed bank as influenced by different methods of rice establishment and weed management practices

AM Rathod, TU Patel, Rutul S Patel and Dhwani Bartwal

Abstract
A field experiment was conducted at the College Farm, Navsari Agricultural University, Navsari (Gujarat) during summer seasons of 2019-20 and 2020-21. The experiment was laid out in split-plot design and replicated four time. Three crop establishment methods were assigned to main plots *viz.* S_1- Direct Seeded Rice, S_2- Conventional Transplanted Rice, S_3- Sprouted Seed (Line sowing) whereas 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 were evaluated on rice cv. NAUR-1. The total weed density (grasses, broad leaved weeds and sedges) and weed dry biomass at 20 and 40 DAS/T were significantly reduced under Conventional transplanted rice (S_2) than other establishment methods of rice (S_1- Direct seeded rice and S3- Sprouted seed line sowing). The Conventional transplanted rice (S_2) had also inferior weed seed counts after crop harvesting on top layer of soil than as compared to remaining establishment methods of rice. Among weed management practices, the total weed density was enhanced at 40 DAS/T over their intensity at 20 DAS/T under Weedy check (W_1), while it declined at 40 DAS/T 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), 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) and Pyrazosulfuron-ethyl 10% WP 15 g ai/ha (Pre) fb Bispyribac sodium 10% SC 25 g ai/ha at 30 DAS/T (W_4). The higher weed seed count/kg of top layer soil was obtained extensively under weedy check (W_1) than other four weed management practices.

Keywords: Establishment method, herbicide, seed bank, weed management

1. Introduction
The elementary idea of weed management is to reduce population and growth of weeds, with the aim of reducing their competition with desired flora. Weed management is particularly challenging in rice eco systems because of the diversity and severity of weed infestation. Weeds compete with crop plants for moisture, nutrients, light, space and other growth factors and these weeds appear much earlier under direct-sown conditions in rice. In the absence of effective control measures, weeds remove the considerable quantity of applied nutrients resulting in a significant yield loss. Type of weeds that establish and compete with a rice crop will be very much influenced by the sowing method and associated field preparation and water management used to establish the crop. (Manna, 1991) [11] Reported a yield reduction of 25 percent in transplanted rice, 32 percent in puddle broadcast rice, and 52 percent in direct sown upland rice due to weeds. In many occasions, a 100 per cent yield reduction was reported under heavy weed infestation conditions (Rao *et al.* 2007) [16]. Crop establishment and weed management techniques are critical in rice farming. Keeping in view of this, the present investigation has been carried out.

2. Materials and Methods
The present investigation 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. For total weed density, the number of grasses, sedges and broad-leaved weeds falling within the one square meter quadrate were counted, recorded and averaged. For weed dry bio mass, weed samples were collected twice at 40 days after planting from 1.0 square meter area and expressed as g/m^2 and second at the time of harvesting and expressed as kg/plot and then converted into kg/ha. These samples were sun dried and then finally dried in the hot-air oven. The dry weight of weeds was recorded when samples attained a constant weight. The original weed data were subjected to square root transformation (x+0.5) on before statistical analysis. For weed seed bank, soil samples of 0.5 kg by weight were taken with the help of core auger at two soil depths, *viz*. 0-10 and 10-20 cm from each treatment plot before sowing of the crop and after harvest of the crop under different establishment methods. Collected soil samples were well labelled with tags and allowed to sun-dry, grounded into fine particles and spread on the petri plates separately in almost homogeneous and uniform layer. The petri plates were marked for each treatment separately and regular watering was done up to 15 days. By providing all favorable conditions, weed seeds were allowed to germinate. The number of germinated weed seedlings were counted under each treatment at 20 days after regular watering. Finally, weed seed counts/kg soil was worked out for each treatment. The data recorded were subjected to statistical analysis as per method of analysis of variance (Panse and Sukhatme, 1967) [12].

3. Results and Discussion

Data illustrated in (Table 1 to 5) indicated that the weed seed bank, total weed density and weed dry biomass were significantly influenced by different methods of establishment and weed management practices in the rice field. Significantly the lowest weed seeds in the soil were recorded with Conventional Transplanted Rice *i.e.*, S_2, while the highest observed in direct seeded rice (S_1), being at par with sprouted seed line sowing (S_3) both at 0-10 and 10-20 cm of soil during season 1 & 2 as well in pooled, respectively. Similar findings were reported by Jha and kewat (2013) [8]. The DSR had higher weed seed counts than conventional transplanting methods of rice. This might be due to the reason that turning up of top layer to lower layer during puddling of land reduced the weed seeds load form shallow rhizosphere, besides hard pan and muddy condition considerably disturbed the weed seeds distribution pattern, whereas, normal land preparation in DSR not much disturbed the weed seeds distribution patter hence reflected as higher weeds in these treatments. Among weed management practices, All the treatment of weed management *i.e.* 2 HW at 20-25 and 40-45 DAS/T (W_2), 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), Pretilachlor 50% EC 1000 g ai/ha (Pre) *fb* Bispyribac sodium 10% SC 25 g ai/ha at 30 DAS/T (W_3) and Pyrazosulfuron 50% EC 1000 g ai/ha (Pre) *fb* Bispyribac sodium 10% SC 25 g ai/ha at 30 DAS/T (W_4) recorded significantly lower down the load of weed seed form top rhizosphere at both 0-10 and 10-20 cm depth compared to weedy check that show the highest value of weed seed bank. This might be due to fact that all the weed management treatments knockdown the weeds either by hand weeding or through application of herbicides before it set the seeds except those weeds emerged later on that fall down the seeds, whereas in weedy condition, weeds were freely established and produced ample seeds, eventually shatter and reserve in rhizosphere that increased the load of seeds in soil. The interaction effect of different establishment methods and weed management practices was found significant for weed seed bank after harvest at 0-10 and 10-20 cm soil depth during both the years of experimentation and in pooled analysis. Conventional Transplanting supplement with any of weed management practices *i.e.*, S_2W_2, S_2W_3, S_2W_4 and S_2W_5 combination found equally effective and significantly reduced the weed seeds load form soil compared to rest of the combination, while highest as noticed under S_2W_1 (DSR + Weedy check). This because the conventional transplanting required puddling and muddy condition that distressed the weed seeds and also disturbed the distribution pattern, besides management of weeds also destroy the weed flush eventually reduced the shattering of weed seeds during crop season resulted lower weed seeds in above combination. Contrary to this, DSR/ Sprouted seed line sowing reported more amount of weed seeds because weed seeds have comparatively more opportunity for reestablished and flourished under normal land preparation, off course, various weed management reduced the weed seeds load but failed to compensate under DSR/sprouted seeded line sowing combination.

The lowest total weed density (26.70, 28.15, 27.43 and 28.80, 29.00, 28.90/m^2 at 20 and 40 DAS/T in year 1, 2 and pooled, respectively) was recorded with transplanted rice (S_2) which was significantly lower than sprouted seed (S_3) line sowing (35.50, 37.15, 36.33 and 37.40, 38.10, 37.75/m^2), whereas, the highest weed density was recorded with direct seeded rice (S_1: 38.80, 41.10, 39.95 and 38.45, 37.25, 37.85/m^2) at 20 and 40 DAS/T in year 1, 2 and pooled, respectively. Kumar *et al.* (2017) [9] and Jehangir *et al.* (2021) [7] also found same results that the transplanted rice recorded significantly lower density of grasses, sedges and broad-leaved weeds as compared to direct seeded rice. Lowest weed population under transplanted rice might be due to puddling along with continuous submergence condition of the crop could have effectively suppressed the weed population and weed seed germination under transplanted rice, similar trend was observed by Subramanian *et al.* (2007) [25] and Parameshwari and Srinivas (2014) [13]. Higher density of weeds was observed in direct seeding rice and sprouted seed line sowing under un-puddled condition is congenial for weed seed germination. The results are being conformity with those of Prakash *et al.* (1995) [14]. Higher weed density in direct seeded rice could also be due to earlier weed germination than resulted in flush of terrestrial and aquatic weeds in early stages of crop growth. Similar results were reported by Sharma and Bahunia (1999) [19]. Baloch *et al.* (2006) [1] noted that weed density and biomass were lower in the transplanted rice plots than the direct-seeded rice plots. In general, conventional transplanting reduced the weeds by 31.34 and 24.50 per cent at 20 DAS/T and 23.65 and 23.44 per cent at 40 DAS/T compared to direct seeded and sprouted seeded line sowing. Among the weed management practices the total weed density was found lower with the application of Pretilachlor 50% EC 1000 g ai/ha (Pre) *fb* Bispyribac sodium 10% SC 25 g ai/ha at 20 and 40 DAS/T (W_3: 14.67, 15.58, 15.13 and 12.33, 11.67, 12.00 in year 1, 2 and pooled, respectively) being statistically at par with W_4 *i.e.* Pyrazosulfuron-ethyl 10% WP 15 g ai/ha (Pre) *fb* Bispyribac sodium 10% SC 25 g ai/ha at 30 DAS/T (16.33, 17.50,16.92 and 13.92, 12.58, 13.25) 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: 16.58, 16.25, 16.42 and 13.58, 12.42, 13.00 no./m^2) at 20 and 40 DAS/T in year 1, 2 and pooled analysis, respectively. The plots treated with pre-emergence application either Pretilachlor or Pyrazosulfuron *fb* Bispyribac recorded lesser total number of weeds (grasses, sedges and broad-leaved weeds) as compared to other weed management practices. The data on weed population at 20 days after sowing clearly indicated that weed population (grasses, broad leaved weeds, sedge and total) in pre-emergence herbicide treated plots either with Pretilachlor or Pyrazosulfuron ethyl (W_3, W_4 and W_5) was significantly lower as compared to rest of the treatment. It undoubtedly indicated that pre-emergence application of herbicides repressed the growth of newly germinated weed seeds and/or seedlings. Thus, it significantly reduced the total weed population during the initial periods of crop growth. Pretilachlor is used in various field crops for selective control of many annual and perennial grasses while Pyrazosulfuron ethyl is effective on broad leaved weeds and annual sedges with considerably control the grasses also. Similarly, at 40 DAS/T, the lower weed population were recorded with combination of pre-emergence application of Pretilachlor or Pyrazosulfuron ethyl supplement with Bispyribac sodium salt or Metsulfuron Methyl + Chlorimuron Ethyl at 30 DAS/T. The data concluded that it is difficult to get effective control in rice culture with a single application of herbicide, hence combination of pre and post emergence herbicide is required to effectively control weeds. It clearly indicated that combination of pre and post emergence herbicides and hand weeding twice during critical weed competition significantly reduced the total weed population during the period of crop growth. Similarly, the results are in agreement with those reported by Sindhu *et al.* (2010) [20] and Singh *et al.* (2016). Better performances of metsulfuron methyl + chlorimuron ethyl in reducing total weed density has also been reported by Ramana *et al.* (2007) [15]. These results are in close proximity with Gangireddy *et al.* (2019) [4], Sharma *et al.* (2020) [18] and Verma *et al.* (2022) [22]. Significantly the highest total weed density was observed with weedy check (61.17, 67.42, 64.29 and 111.58, 116.33, 113.96 no./m^2 in year 1, 2 and pooled, respectively) at 20 and 40 DAS/T. Uninterrupted growth of weeds with maximum utilization of the growth resource like moisture, nutrient and sun light offered stiff competition to the crop and might have been the unavoidable reason for such result. Further, weed population in W_3, W_4 and W_5 was found less compared to 2 HW at 20 and 40 DAS/T, because first the hand weeding was imposed after 20 DAS/T and second operated at 40 DAS/T, so only one weeding operation was received by W_2, treatment at second weed count. The interaction between establishment methods and weed management practices was found to be significant at all growth stages. Significantly higher reduction in total weed density was observed under conventional transplanted rice and managed the weeds with application of Pretilachlor 50% EC 1000 g ai/ha (Pre) *fb* Bispyribac sodium 10% SC 25 g ai/ha at 30 DAS/T (S_2W_3) which was found at par with S_2W_4 and S_2W_5 during 2020, 2021 and in pooled at 20 DAS/T, whereas, at 40 DAS/T same was found at par during 2021 and pooled analysis. Significantly the highest weed density was found in S_1W_1 *i.e.*, in direct seeded rice under weedy check control. Lowest weed population under transplanted rice might be due to special land preparation and continuous submerge condition of the crop could have effectively suppressed the weed population and weed seed germination under transplanted rice, besides managed the weeds with sequential application of herbicides (W_3, W_4 and W_5) knockdown the weeds effectively during growing season. Similar trend was observed by Subramanian *et al.* (2007) [25] and Parameshwari and Srinivas (2014) [13]. Higher density of weeds was observed in direct seeding of dry seeds and direct seeding of sprouted seeds. The un-puddled condition in direct seeded rice and uninterrupted growth of weeds under weedy check is congenial atmosphere for weed seed germination and establishment. The results are in conformity with those of Kumar *et al.* (2017) [9]. Similar trend was also observed by (Gopinath *et al.* 2012 and Veeraputhiran and Balasubramanian 2013) [5, 27].

Total dry weight of weeds varied significantly due to different crop establishment methods at all the growth stages during both the years. Among the establishment methods, transplanted rice (S_2) recorded significantly the lowest weed dry biomass (58.08, 56.54, 57.31 g/m^2 and 345, 323, 334 kg/ha at 40 DAS/T and at harvest, respectively). Further, direct seeded rice (S_1) recorded significantly the highest weed dry biomass (71.49, 67.98, 69.74 g/m^2 and 465, 456, 461 kg/ha at 40 DAS/T and at harvest) which was found at par with S_3 (Sprout seed line sowing) 71.20, 67.59 and 69.40 at 40 DAS/T during both years and in pooled data. The highest dry matter was recorded in direct seeded rice over other establishment methods owing to better conditions for weeds emergence and its survival. Conventional transplanted rice resulted in lower weed dry matter mainly because of puddling which recorded lesser emergence of deeply placed weed seeds. These results are in agreement with the findings of Singh *et al.* (2005a) [22] and Singh *et al.* (2005b) [23]. Further, better performance of the rice in transplanted puddled soil condition was also reported by Subbulakshmi and Pandian (2002) [24] as puddling decreased percolation loss of water and favourable land submergence which had inhibitory effect on the growth and dry matter build up by weeds. Addition with this, dry weight of weeds increased progressively when rice was sown directly under un-puddled soil condition. Rice transplanted in puddled soil statistically decreased the dry matter accumulation by weeds as compared to the rice was sown in un-puddled condition conformed earlier by Singh *et al.* (2005a) [22] and Baloch *et al.* (2006) [1]. Among the weed management practices, at 40 DAS/T, 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) registered significantly lower dry weight (46.10, 35.62 and 40.86 g/m^2 during season 1, 2, and pooled, respectively) and found significantly superior than 2 HW at 20-25 and 40-45 DAS/T (W_2: 70.13, 83.99 and 77.06 g/m^2). Further, it was found at par 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: 49.05, 36.74 and 42.89 g/m^2) as well as 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: 48.81, 36.14, and 42.47 g/m^2) during the years of 2020, 2021 and in pooled. However, at harvest, significantly lower weed dry matter was observed in 2 HW at 20 and 40 DAS/T (W_2) *i.e.*, 206, 198 and 202 kg/ha in Season 1, 2 and pooled, respectively which remain statistically similar with Pretilachlor 50% EC 1000 g ai/ha (PRE) *fb* Bispyribac sodium 10% SC 25 g ai/ha at 30 DAS/T (W_3: 218, 208, and 213 kg/ha), Pyrazosulfuron-ethyl 10% WP 15 g ai/ha (PRE) *fb* Bispyribac sodium 10% SC 25 g ai/ha at 30 DAS/T (W_4: 227, 211 and 219 kg/ha) 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: 213, 207 and 210 kg/ha) during both the years and in pooled data. Contrary to this, significantly the highest weed dry biomass was recorded in Weedy check (W_1: 120.53, 127.72 and 124.12 g/m^2 and 1230, 1226 and 1228 kg/ha) at both the intervals during Y_1, Y_2 and pooled analysis, respectively. This might be due to the Pretilachlor and Pyrazosulfuron being a broad-spectrum herbicide has effectively controlled the weed flora at early stages. Furthermore, hand weeding twice at 20 & 40 DAT helped in effective removal of weeds at both early and later stages which helped in reducing the weed density and weed dry weight reported by Chadachanakar *et al.* (2017) [2]. Among the post emergence herbicide, Bispyribac sodium and Chlorimuron ethyl + Metsulfuron-methyl recorded lower weed dry matter, this is due to complementary effect of inhibitory action on broad spectrum weed flora under sequential application of herbicides. Overall, lower weed population recorded in treatment in which sequential application of herbicides because of application of pre-emergence herbicides kill first flush of weeds and post emergence herbicides kill weeds in the critical period of crop weed competition reducing the present weed which ultimately reduce the dry weight of weeds up to harvest. Pretilachlor belongs to the chloroacetamide class of herbicides. It is selective pre-emergence broad spectrum herbicide which inhibits growth and reduces cell division. It affects the early development of susceptible plants by the inhibition of protein, nucleic acid, lipid or Gibberelic acid syntheses. The Bispyribac-sodium and Metsulfuron methyl + Chlorimuron ethyl mode of action are to inhibit the enzyme acetolactate synthase (ALS) and the subsequent biosynthesis of essential amino acids, which in turn interferes with cell division and causes cessation of plant growth. This is used to control grasses, sedges and broad-leaved weeds, especially *Echinochloa* spp. and annual sedges. Rawat *et al.* 2012, Upasani *et al.* (2012) [17, 26] and Kumar *et al.* (2013) [10] have also reported that Bispyribac-sodium brought significant reduction of *Cyperus* species in rice crop. Overall response was ascribing to pre-emergence application of herbicides did not allow to germinate weed seeds to large extend due to its killing effect resultantly very few weeds have been emerged out, while under weedy check treatment, due to no management of weeds, they grew fully resulting in increased weed population eventually reflected in dry weight of weeds. Further, killing of weeds by itself as herbicide compound would be very active during the initial period of application. However, during later stage hand weeding found to be superior method of weed management compare to herbicide application because, gradual decomposition of herbicide compound as the day proceeds and its effectiveness become reduced eventually. Un-weeded control recorded the highest weed dry matter by weeds owing to greater competitive ability than crop because weeds were freely allowing to grow in plot throughout the crop growth period and this put forth the highest biomass under weedy condition (Dixit and Varshney 2008 and Hemalatha *et al.* 2017) [3, 6]. The interaction between methods of establishment and weed management practices (S x W) was found to be significant at 40 DAS/T during 2021 and in pooled analysis only, while at harvest, significance was noted during season 1, season 2 as well as in pooled analysis. Significantly lower dry weight at 40 DAS/T was recorded under (S_2W_3) conventional transplanting with Pretilachlor 50% EC 1000 g ai/ha (pre) *fb* Bispyribac sodium 10% SC 25 g ai/ha at 30 DAS/T which was found at par with S_1W_3, S_1W_4, S_1W_5, S_2W_4, S_2W_5, S_3W_3, S_3W_4 and S_3W_5 during 2021 while in pooled, it was established at par relation with S_1W_3, S_1W_5, S_2W_4, S_2W_5, S_3W_3, and S_3W_5. Moreover, at harvest, S_2W_2 (Conventional transplanting + 2 HW at 20 and 40 DAS/T) recorded significantly lower dry weight which found at par with S_1W_2, S_1W_3, S_1W_4, S_1W_5, S_2W_3, S_2W_4, S_2W_5, S_3W_2, S_3W_3, S_3W_4, and S_3W_5 during 2020, whereas during 2021 and in pooled analysis, treatment combination of S_2W_3, S_2W_4 and S_2W_5 was found at par with S_2W_2. It indicated that, conventional transplanting proved their potentiality with pre-emergence application of either Pretilachlor 50% EC 1000 g ai/ha or Pyrazosulfuron-ethyl 10% WP 15 g ai/ha *fb* Bispyribac sodium 10% SC 25 g ai/ha at 30 DAS/T by destroying weeds correspondingly reducing the dry weight of weeds. Significantly the highest weed dry biomass was observed in (S_1W_1) Weedy check control with direct seeded rice (140.69 and 138.08 g/m2 during 2020 and in pooled, 1459, 1432 and 1445 kg) because un controlled growth of weeds without management.

Table 1: Weed seed bank/kg of soil after harvesting of rice crop at varying soil depth as influenced by methods of establishment and weed management practices

Treatment	0-10 cm			10-20 cm		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Main plot: Methods of Establishment (S)						
S_1: Direct Seeded Rice	54.15	50.90	52.53	42.75	40.85	41.80
S_2: Conventional Transplanted Rice	30.10	34.15	32.13	28.95	23.90	26.43
S_3: Sprouted Seeds (Line sowing)	52.55	49.15	50.85	40.80	39.75	40.28
S.Em ±	0.52	0.71	0.44	0.84	0.45	0.47
C.D. (P=0.05)	1.82	2.46	1.36	2.89	1.54	1.46
CV (%)	7.56	9.00	8.28	9.98	7.71	8.28
Sub Plot: Weed Management (W)						
W_1: Weedy check (Control)	71.25	73.83	72.54	52.50	49.92	51.21
W_2: 2 HW at 20-25 and 40-45 DAS/T	38.00	36.08	37.04	31.75	30.58	31.17

W_3: Pretilachlor 50% EC 1000 g ai/ha (Pre) *fb* Bispyribac sodium 10% SC 25 g ai/ha at 30 DAS/T	38.50	37.08	43.07	34.67	30.33	32.50
W_4: Pyrazosulfuron-ethyl 10% WP 15 g ai/ha (Pre) *fb* Bispyribac sodium 10% SC 25 g ai/ha at 30 DAS/T	41.33	41.08	41.21	34.83	31.92	33.38
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	38.92	35.58	37.25	33.75	31.42	32.58
S.Em ±	1.00	1.15	0.66	0.81	0.70	0.47
C.D. (P=0.05)	2.88	3.30	1.86	2.33	2.01	1.31
CV (%)	7.26	7.48	7.6	7.52	6.97	7.28
Interactions						
(S × W)	S	S	S	S	S	S
Other interaction (if any)	NS	NS	S ×W×Y	NS	NS	S ×W×Y

Table 2: Interaction effect of different methods of rice establishment and weed management on weed seed bank/kg of soil after harvesting of rice crop at 0-10 cm and 10-20 soil depth

Weed Management (W)	Methods of Establishment (S)																	
	0-10 cm depth									10-20 cm depth								
	2019-20			2020-21			Pooled			2019-20			2020-21			Pooled		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
W_1	87.50	40.75	85.50	76.00	69.25	76.25	81.75	55.00	80.88	63.75	49.25	44.50	58.00	39.50	52.25	60.88	44.38	48.38
W_2	44.00	28.75	41.25	42.50	25.00	40.75	43.25	26.88	41.00	35.75	21.75	37.75	34.50	21.50	35.75	35.13	21.63	36.75
W_3	44.50	25.25	45.75	45.00	24.50	41.75	44.75	24.88	43.75	40.50	24.75	38.75	36.25	19.25	35.50	38.38	22.00	37.13
W_4	49.00	26.75	48.25	48.75	28.25	46.25	48.88	27.50	47.25	37.50	25.00	42.00	38.75	20.25	36.75	38.13	22.63	39.38
W_5	45.75	29.00	42.00	42.25	23.75	40.75	44.00	26.38	41.38	36.25	24.00	41.00	36.75	19.00	38.50	36.50	21.50	39.75
SEm ±	1.74			1.99			0.93			1.41			1.21			0.65		
C.D. (P=0.05)	4.50			5.71			2.63			4.04			3.48			1.85		
CV (%)	7.63			8.9			8.28			7.52			6.97			7.28		

Table 3: Total weed density and weed dry biomass as influenced by different methods of establishment and weed management practices

Treatment	Total weed density/m²						Weed dry biomass					
	At 30 DAS/T			At 40 DAS/T			40 DAS/T (g/m²)			At harvest (kg/ha)		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Main Plot: Methods of Establishment (S)												
S_1	5.88 (38.80)	6.05 (41.10)	5.97 (39.95)	5.59 (38.45)	5.44 (37.25)	5.52 (37.85)	8.26 (71.49)	7.91 (67.98)	8.08 (69.74)	19.58 (465)	19.22 (456)	19.40 (461)
S_2	4.99 (26.70)	5.13 (28.15)	5.06 (27.43)	4.88 (28.80)	4.81 (29.00)	4.84 (28.90)	7.53 (58.08)	7.35 (56.54)	7.44 (57.31)	17.47 (345)	16.83 (323)	17.15 (334)
S_3	5.69 (35.50)	5.80 (37.15)	5.74 (36.33)	5.54 (37.40)	5.53 (38.10)	5.53 (37.75)	8.25 (71.20)	7.90 (67.59)	8.08 (69.40)	19.15 (446)	19.14 (451)	19.14 (448)
S.Em ±	0.13	0.11	0.08	0.09	0.10	0.07	0.17	0.06	0.09	0.27	0.56	0.31
C.D. (P=0.05)	0.44	0.37	0.26	0.31	0.36	0.21	0.60	0.21	0.28	1.36	1.93	0.96
CV (%)	10.24	8.45	9.37	9.59	8.87	8.24	11.67	8.54	8.38	9.80	13.57	10.58
Sub Plot: Weed Management (W)												
W_1	7.81 (61.17)	8.21 (67.42)	8.01 (64.29)	10.53 (111.58)	10.79 (116.33)	10.66 (113.96)	10.97 (120.53)	11.29 (127.72)	11.13 (124.12)	34.91 (1230)	34.70 (1226)	34.80 (1228)
W_2	7.71 (59.58)	7.77 (60.58)	7.74 (60.08)	4.79 (23.00)	4.66 (20.92)	4.72 (21.96)	8.37 (70.13)	9.17 (83.99)	8.77 (77.06)	14.37 (206)	14.07 (198)	14.22 (202)
W_3	3.88 (14.67)	4.00 (15.58)	3.94 (15.13)	3.71 (12.33)	3.52 (11.67)	3.62 (12.00)	6.77 (46.10)	6.00 (35.62)	6.39 (40.86)	14.73 (218)	14.41 (208)	14.57 (213)
W_4	4.09 (16.33)	4.23 (17.50)	4.16 (16.92)	3.85 (13.92)	3.66 (12.58)	3.75 (13.25)	6.97 (49.05)	6.10 (36.74)	6.53 (42.89)	15.05 (227)	14.42 (211)	14.74 (219)
W_5	4.12 (16.58)	4.08 (16.25)	4.10 (16.42)	3.80 (13.58)	3.68 (12.42)	3.74 (13.00)	6.98 (48.81)	6.04 (36.14)	6.51 (42.47)	14.61 (213)	14.38 (207)	14.49 (210)
S.Em ±	0.09	0.08	0.12	0.12	0.07	0.08	0.24	0.10	0.11	0.48	0.47	0.29
C.D. (P=0.05)	0.27	0.32	0.38	0.34	0.22	0.24	0.69	0.29	0.32	1.36	1.35	0.82
CV (%)	8.87	7.65	7.28	7.67	7.87	7.44	10.38	7.46	8.09	8.80	8.86	8.83
Interactions												
(S × W)	S	S	S	NS	S	S	NS	S	S	S	S	S
Other interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Figure in parenthesis refers to original value and outside the parenthesis indicates transformed ($\sqrt{X+0.5}$) value

Table 4: Interaction effect of different methods of rice establishment and weed management on total weed density

Weed Manag-Ement (W)	Total weed density/m²														
	Methods of Establishment (S)														
	40 DAS/T (g/m²)									At harvest (kg/ha)					
	2019-20			2020-21			Pooled			2020-21			Pooled		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
W_1	8.61 (73.75)	6.85 (46.75)	7.97 (63.00)	8.96 (79.75)	7.23 (51.75)	8.43 (70.75)	8.78 (76.75)	7.04 (49.25)	8.20 (66.88)	11.18 (124.50)	9.99 (99.25)	11.21 (125.25)	11.17 (124.38)	9.76 (94.88)	11.05 (121.63)
W_2	8.40 (70.25)	6.69 (44.50)	8.03 (64.00)	8.58 (73.25)	6.72 (44.75)	8.01 (63.75)	8.49 (71.75)	6.71 (44.63)	8.02 (63.88)	4.77 (22.25)	4.44 (19.25)	4.77 (22.25)	4.81 (22.75)	4.42 (19.13)	4.94 (24.00)
W_3	4.02 (15.75)	3.56 (12.25)	4.06 (16.00)	4.12 (16.50)	3.77 (13.75)	4.12 (16.50)	4.07 (16.13)	3.67 (13.00)	4.09 (16.25)	3.44 (11.50)	3.12 (9.25)	3.99 (15.50)	3.68 (13.25)	3.24 (10.00)	3.93 (15.13)
W_4	4.27 (17.75)	3.74 (13.50)	4.26 (17.75)	4.38 (18.75)	3.93 (15.00)	4.38 (18.75)	4.32 (18.25)	3.83 (14.25)	4.32 (18.25)	3.70 (13.25)	3.19 (9.75)	4.09 (16.25)	3.86 (14.50)	3.34 (10.88)	4.06 (16.00)
W_5	4.11 (16.50)	4.11 (16.50)	4.14 (16.75)	4.21 (17.25)	3.99 (15.50)	4.06 (16.00)	4.16 (16.88)	4.05 (16.00)	4.10 (16.38)	4.13 (16.75)	3.31 (10.50)	3.60 (12.50)	4.07 (16.25)	3.45 (11.50)	3.69 (13.25)
SEm ±	0.09			0.08			0.12			0.07			0.08		
C.D. (P=0.05)	0.27			0.32			0.38			0.22			0.24		
CV (%)	8.87			7.65			7.28			7.87			7.44		

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 weed dry biomass

Weed Manag-Ement (W)	Methods of Establishment (S)														
	Weed dry biomass														
	40 DAS/T (g/m²)						At harvest (kg/ha)								
	2020-21			Pooled			2019-20			2020-21			Pooled		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
W_1	11.88 (140.69)	10.19 (103.33)	11.81 (139.13)	11.77 (138.08)	10.04 (100.50)	11.58 (133.80)	38.14 (1459)	29.91 (899)	36.68 (1356)	37.84 (1432)	28.79 (851)	37.29 (1395)	37.99 (1445)	29.44 (875)	36.98 (1375)
W_2	9.55 (90.87)	8.50 (71.78)	9.47 (89.31)	9.04 (81.62)	8.06 (64.76)	9.22 (84.78)	14.72 (216)	13.98 (195)	14.41 (208)	14.50 (210)	13.15 (174)	14.54 (211)	14.61 (213)	13.57 (184)	14.48 (209)
W_3	5.95 (34.98)	5.90 (34.36)	6.16 (37.50)	6.48 (42.02)	6.21 (38.31)	6.47 (42.25)	14.98 (225)	14.40 (208)	14.82 (221)	14.58 (213)	14.02 (197)	14.63 (214)	14.78 (219)	14.21 (202)	14.72 (218)
W_4	6.16 (37.58)	6.01 (35.73)	6.12 (36.91)	6.62 (44.23)	6.40 (40.80)	6.58 (43.66)	15.33 (236)	14.65 (215)	15.17 (231)	14.60 (215)	14.06 (198)	14.62 (220)	14.97 (225)	14.35 (207)	14.89 (225)
W_5	6.02 (35.79)	6.14 (37.50)	5.96 (35.12)	6.52 (42.73)	6.48 (42.19)	6.53 (42.50)	14.75 (217)	14.39 (207)	14.68 (215)	14.56 (212)	13.97 (195)	14.60 (214)	14.65 (214)	14.18 (201)	14.64 (215)
SEm ±	0.10			0.11			0.48			0.47			0.29		
C.D. (P=0.05)	0.29			0.32			1.36			1.35			0.82		
CV (%)	7.46			8.09			8.80			8.86			8.83		

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

4. 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 eventually recorded higher weed seed bank, total weed density and their dry weight throughout the experiment. Whereas, significant lower values of weed seed bank, total weed density and dry weigh was observed with transplanted rice (S_2) and in 2 HW at 20-25 and 40-50 DAS/T (W2) treatment. Moreover, weed dry biomass was significantly reduced 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), 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).

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