Agriculture Association of Textile Chemical and Critical Reviews Journal (2024) 324-329

AATCC Review

15 June 2024: Received
18 July 2024: Revised
21 August 2024: Accepted
23 September 2024: Available Online

https://aatcc.peerjournals.net/

Original Research Article   Open Access

Weed dynamics as influenced by different direct seeded establishment methods and new generation herbicidal combination in rice (*Oryza sativa* L.)

R. Suganya* and Sanjay D. J.

Department of (Weed Science), Regional Plant Quarantine Station, Meenambakkam, Chennai, Tamil Nadu - 600 016.

ABSTRACT

Weeds are the greatest menace in direct seeded rice (DSR) which must be managed effectively to augment yield and economics in DSR. Therefore, a field experiment was conducted at Periyanarkunam during Navarai 2021. The main treatments comprised three direct seeded rice establishment methods viz., dry, drum, manual wet seeded rice. The -sub-treatments are nine weed management practices and are made up of a combination of herbicides with hand weeding viz., application of bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} on 8 DAS (Days After Sowing) (PE), application of triafamone 20% + ethoxysulfuron 10% WG @ 200 g ha^{-1} on 12 DAS (EPoE), application of metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS (PoE), twice hand weeding on 25 and 45 DAS and unweeded control. Among the main treatments drum seeded rice recorded the lowest weed population, dry matter production, the highest weed control efficiency, and the highest grain yield which is on par with manual wet seeded rice. However, manual wet-seeded rice led to a higher cost of cultivation with a lower benefit-cost ratio. Hence, drum-seeded rice is an economically feasible method of direct-seeded rice establishment compared to others. Regarding the weed management practices evaluated application of bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} on 8 DAS (PE) fb (followed by) application of metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS (PoE) fb hand weeding on 45 DAS (S_8) registered the similar trend. Hence, drum-seeded rice coupled with S_8 is an economically feasible method for effective control of weeds.

Keywords: *Benefit-cost ratio, direct seeded rice, new generation herbicides, weed, yield.*

Introduction

Rice (*Oryza sativa* L.) is an important staple food crop accounting major share in the total food grain production. In India, rice occupies 43.90 million hectares with a production of 114.45 million tonnes and productivity of 2.61 t/ha (Directorate of Economics and Statistics, 2022). In the Tamil Nadu area, production and productivity under rice are 2.21 million hectares, 8.07 million tonnes, and 3.65 t/ha respectively [1]. Transplanting is the most common method of rice cultivation which is laborious, consumes more water, is time intensive, and incurs a lot of expenditure on raising nursery, uprooting, and transplanting. Due to a shortage of labor during the peak period of transplanting, unstable supply of monsoon rains, decline in underground water and rising production costs need the search for an alternative to the traditional puddled transplanting of rice [2]. Direct-seeded rice offers the advantages of quicker and easier planting, less labor intensive, saving labor costs by avoiding raising of seedlings, uprooting, and transplanting, 10-12 days prior to crop maturity, reduced methane emission, high tolerance to water scarcity and often higher profits in areas with ensured water supply. Drum seeding of rice offer benefits *viz*., light in weight, easy to transport, gender-neutral, solves labor scarcity problem, sowing more area in a short period, uniform spacing, reduced production cost and increased the returns rupee^{-1} invested [3].

Corresponding Author: **R. Suganya*

DOI: https://doi.org/10.21276/AATCCReview.2024.12.03.324

Weeds are the greatest menace in rice because they pose serious problems by causing severe competition with crop plants for the nutrients, moisture, solar energy, and space. Absence of effective weed control measures, yield losses are greater in -direct-seeded rice than in transplanting rice, which vary from 50 to 91 per cent [4]. The critical period of crop-weed competition in rice is influenced by different rice establishment methods *viz*., transplanted rice (20-40 DAT), wet-seeded rice (15-60 DAS), dry-seeded rice (15-60 DAS), rainfed direct-seeded rice (0-90 DAS) and upland direct seeded rice (30 DAS) [5]. The control of weeds in rice is a challenging task for effective crop production as their presence leads to significant reductions in crop yield and quality, which in turn reduces productivity and profitability. Thus, effective weed control is one of the prerequisites for better growth and productivity of rice in all establishment methods.

Currently, herbicide has become the most important weed management tool as it offers a timely, effective, economical, and practical way of weed control [6]. Judicious selection of herbicide at the right time, right dose, and right method helps to effectively manage weeds and increase the crop yield. Application of a single herbicide does not provide effective weed control during the entire growing period as weed flora is very diverse and may develop herbicide resistance in weeds. Hence, sequential application of pre and post-emergence herbicides with hand weeding, use of combined application of herbicides in the form of tank-mix or ready-mix having different modes of action have a capacity to broad-spectrum weed control as well as delaying the development of herbicide resistance. New-generation herbicidal mixtures are readily available in the market which lowers the rate of use, reduces herbicide injury to crops, broad-spectrum weed control, minimizes the cost of application and lessens the problem of residual build-up with high efficiency. Keeping the above points in view, the field experiment was conducted at Periyanarkunam during *Navarai*, 2021 to study the weed dynamics as influenced by different direct seeded establishment methods and new generation herbicidal combinations in rice (*Oryza sativa* L.).

Materials and Methods

The experiment was conducted at Periyanarkunam, Melbhuvanagiri block, Cuddalore district during *Navarai,* 2021. The experimental field soil was low, medium, and high in available nitrogen, phosphorous, and potassium respectively and the soil was clay loam in texture. The weather of the Melbhuvanagiri block during observation is the mean maximum temperature (36.5^0 C), mean minimum temperature (25.8^0 C), and relative humidity (83.11 percent). In this experiment, the performance of different -direct-seeded rice establishment methods and weed management practices were evaluated. The experiment was conducted in a split plot design and replicated thrice. The plot size of the experiment was 5 × 4 m (gross plot) and 4.8 × 3.8 m (net plot). The treatments consists of three direct seeded establishment methods as main treatment *viz.*, dry seeded rice (M_1), drum seeded rice (M_2), manual wet seeded rice (M_3) and nine weed management practices as sub treatments *viz.*, unweeded Control (S_1), twice hand weeding on 25 and 45 DAS (S_2), bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} on 8 DAS (Pre emergence) (PE) fb HW at 45 DAS (S_3), triafamone 20% + ethoxysulfuron 10% WG @ 200 g ha^{-1} on 12 DAS (Early post) (EPoE) fb HW at 45 DAS (S_4), metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS (Post emergence) (PoE) fb HW at 45 DAS (S_5), bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} on 8 DAS (PE) fb metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS (PoE) (S_6), triafamone 20% + ethoxysulfuron 10% WG @ 200 g ha^{-1} on 12 DAS (EPoE) fb metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS (PoE) (S_7), bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} on 8 DAS (PE) fb metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS (PoE) fb HW at 45 DAS (S_8) and triafamone 20% + ethoxysulfuron 10% WG @ 200 g ha^{-1} on 12 DAS (EPoE) fb metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS (PoE) fb HW at 45 DAS (S_9).

The variety taken for the experiment was ASD 16. A fertilizer schedule of 120: 40: 40 NPK kg ha^{-1} was adopted as the common practice for the experiment. 50 percent of nitrogen and potassium, and 100 percent of phosphorous were given basally. The remaining half doses of nitrogen and potassium were given into two splits during the maximum tillering stage and panicle primordium initiation (PPI) stage. Nitrogen, phosphorous, and potassium were supplied through urea, single super phosphate, and muriate of potash respectively. The required quantity of herbicides was sprayed as per the treatment schedule and weeding was done on 25 and 45 DAS. The granular herbicide was applied with dry sand @ 50 kg ha^{-1}. The calculated amounts of herbicides were sprayed with a knapsack sprayer equipped with a flood jet nozzle using 500 L of water ha^{-1}. A thin film of water was retained at the time of both liquid and granular herbicide application.

Total weed population, and weed dry matter production were recorded at 30 and 60 DAS and their original values were transformed using $\sqrt{x+0.5}$ formula. Wherever statistical significance was observed, the critical difference at 0.05 level of probability was worked out in Agris software. Weeds from four quadrants of 0.25 m^{-2} area placed at random in each net plot were collected on 30 and 60 DAS.

The roots were removed and then dried in a hot air oven at 80°C ± 5°C for 48 hrs and weed dry matter production was computed and expressed in g m^{-2}. Weed control efficiency was calculated based on the weed population recorded in each treatment at 30, 60 DAS, and at harvest using the formula recommended by [7].

$$\text{WCE (\%)} = \frac{\text{weed population in the control plot} - \text{weed population in the treated plot}}{\text{weed population in the control plot}} \times 100$$

Weed samples collected at the time of harvesting from the individual plots were dried under shade and then oven-dried, powdered in Willy Mill and separately analyzed as per the standard procedures. The nutrient removal by weeds was computed from their respective elementals (NPK) concentration and dry matter production and presented in kg ha^{-1}.

Results and Discussion

Weed flora

The predominant weed species observed during the experiment were *Echinochloa colona, Echinochloa crus-galli* among grasses, *Cyperus difformis, Cyperus rotundus* among sedges and *Eclipta alba, Bergia capensis* among broad-leaved weeds. Similar weed species have been found in dry direct seeded rice [8].

Grasses, sedges, and broad-leaved weeds population

All the methods of direct seeded rice establishment and weed management practices significantly influenced grasses, sedges and broad-leaved weed populations during *Navarai* 2021 (Table 1).

Among the main treatments evaluated, drum-seeded rice (M_2) registered the lowest grasses (16.73 and 50.24 m^{-2}), sedges (10.50 and 32.77 m^{-2}), and broad-leaved weed population (6.10 and 26.87 m^{-2}) at 30 and 60 DAS respectively, which was on par with manual wet seeded rice (M_3). The highest number of grasses, sedges, and broad-leaved weeds were recorded under dry-seeded rice (M_1). The dominance of grasses was more compared to sedges and broadleaved weeds in dry DSR as reported by [9].

Regarding the weed management practices tested, at 30 DAS application of bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} PE on 8 DAS fb metsulfuron methyl 10% + chlorimuron ethyl 10% WP @ 20 g ha^{-1} PoE on 25 DAS fb hand weeding on 45 DAS (S_8) recorded the lowest grasses (10.08 m^{-2}), sedges (6.07m^{-2}) and broad-leaved (3.65 m^{-2}) weed population which was on par with S_6. Whereas at 60 DAS, S_8 alone recorded the lowest population of grasses (26.09 m^{-2}), sedges (16.90 m^{-2}) and broad-leaved (14.01 m^{-2}) weeds. This could be attributed to the effective control of weeds at the germination phase by application of pre-emergence herbicide and a significant decrease at the later growth stage as late emerging weeds were controlled by application of post-emergence herbicides [10]. The highest population of grasses (140.17 m^{-2}), sedges (88.59 m^{-2}) and broad-leaved (72.40 m^{-2}) weeds at 60 DAS were recorded under unweeded control (S_1). Weeds compete with the crop more because they are spontaneous, highly persistent, prolific seed producers and have wider adaptability to adverse conditions and thus produce higher numbers of grasses, sedges and broad-leaved weeds in unweeded control.

Total weed population and dry matter production

All the methods of direct seeded rice establishment and weed management practices significantly influenced total weed population (TWP) and total dry matter production (TDMP) during *Navarai* 2021.

Among the main treatments evaluated, drum-seeded rice (M_2) registered the lowest TWP (33.33 and 109.88 m^{-2}) and TDMP (5.45 and 64.14 g m^{-2}) at 30 and 60 DAS respectively, which was on par with manual wet-seeded rice (M_3). This might be due to the disturbance of weed seed banks in puddled fields limiting the germination of weeds when compared to aerobic conditions. This was in accordance with the findings of [11]. The highest TWP and TDMP were recorded under dry-seeded rice (M_1). Weed problems were greater in dry DSR because the conditions immediately after sowing under dry DSR are most conducive to weed growth [12]. Similar findings were also reported by [13].
Regarding the weed management practices tested, at 30 DAS application of bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} PE on 8 DAS fb metsulfuron methyl 10% + chlorimuron ethyl 10% WP @ 20 g ha^{-1} PoE on 25 DAS fb hand weeding on 45 DAS (S_8) recorded the lowest TWP (19.80 m^{-2}) and TDMP (3.08 g m^{-2}) which was on par with S_6. Whereas at 60 DAS, S_8 alone recorded the lowest TWP (56.99 m^{-2}) and TDMP (32.70 g m^{-2}). This might be due to the application of an appropriate combination of pre and post-emergence herbicides led to a broad spectrum of weed control. This result was supported by [14] mentioned that the application of herbicides used in combination has been very effective against complex weed flora in rice. According to [15] bensulfuron methyl comes under the sulfonylurea group of herbicides which controls the complex weed flora at initial stages and pretilachlor will control the weeds by inhibiting the cell division and protein synthesis, whereas the -post-emergence application was effective against broad-leaved weeds and the weeds emerged at later stages was removed by hand weeding. The highest TWP (107.36 and 301.17 m^{-2}), and TDMP (18.25 and 177.19 g m^{-2}) at 30 and 60 DAS were recorded under unweeded control (S_1).

Weed control efficiency and weed index

Among the main treatment evaluated, drum seed rice (M_2) registered the highest weed control efficiency (WCE) and the lowest weed index (WI) (Fig. 1). Weed control efficiency (WCE) was generally dependent on weed population but fluence largely by weed control treatments. This result was supported by [15]. The lowest WCE and the highest weed index were recorded under dry seed rice (M_1).
Regarding the weed management practices tested, application of bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} PE on 8 DAS fb metsulfuron methyl 10% + chlorimuron ethyl 10% WP @ 20 g ha^{-1} PoE on 25 DAS fb hand weeding on 45 DAS (S8) registered the highest WCE and the lowest WI. Similar findings of WCE were earlier emphasized by [16]. The highest weed index was recorded under unweeded control (S1). Similar trend has also been observed by [17].

Nutrient removal by weeds

Among the rice establishment methods evaluated, drum seeded rice (M_2) registered the lowest nutrient removal *viz*., nitrogen (24.84), phosphorus (5.55) and potassium (39.69) kg ha^{-1} which was on par with manual wet seeded rice (M_3). This agrees with the findings of [18]. NPK uptakes by weeds were total reverse to that notice in case of crops. The highest nutrient removal by weeds was recorded under dry-seeded rice (M_1). Dry tillage and aerobic environment due to lack of flooding conditions contribute to maximum percent removal of nitrogen, phosphorus, and potassium by weeds under dry DSR [19].
Regarding the weed management practices tested, application of bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} PE on 8 DAS fb metsulfuron methyl 10% + chlorimuron ethyl 10% WP @ 20 g ha^{-1} PoE on 25 DAS fb hand weeding on 45 DAS (S_8) recorded the lowest nutrient removal by weeds of 13.53, 4.17 and 33.53 N, P and K kg ha^{-1} respectively. Effective control of weeds enabled the low absorption of nutrients by weeds. This might be due to the control of a broad spectrum of weeds whichin turn resulted in lower biomass accumulation of weeds [20]. The high nutrient removal of 40.96, 7.05 and 49.76 kg ha^{-1} N and P and K respectively were recorded under unweeded control (S_1). This might be due to the unrestricted proliferation of weeds in direct seeded rice which is in line with the report of [21].

Grain yield and economics

Among the main treatments evaluated, drum-seeded rice (M_2) registered the highest grain yield (4824 kg ha^{-1}) which was on par with manual wet-seeded rice. However, drum-seeded rice recorded higher BCR (2.22) compared to manual wet-seeded rice (Table 2). These are in line with the findings of [22] and they have observed that drum seeding recorded almost similar grain yield as transplanting and maximum net return and -benefit-cost ratio as it was less labor intensive than another method. Similarly [10] also observed that among the different rice establishment methods drum seeding recorded the highest grain yield compared to dry seeding. The lowest grain yield was recorded under dry-seeded rice.
Regarding the weed management practices tested, -pre-emergence application of bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} on 8 DAS -FB -post-emergence application of metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS FB hand weeding on 45 DAS (S_8) registered the highest grain yield (5639 kg ha^{-1}) and benefit-cost ratio (2.39). This might be due to the highest growth and yield attributes of rice because of better control of weeds at the early stage which was in conformity with [23] reported better performance of bensulfuron methyl plus pretilachlor combination in controlling weeds and increasing yield in rice. The lowest grain yield was recorded under unweeded control (S_1). The lowest grain yield in unweeded control is due to crop weed competition. Similar findings were reported by [24] mentioned that the reduction of grain yield in weedy check was possibly due to severe weed infestation in the crop field. The weeds growing freely reached vigor enough to compete with the crop plants for nutrients, moisture, and sunlight throughout the growing season hence, suppressing the crop plants resulted in reduced crop yield to a greater extent.From the above study, it can be concluded that drum-seeded rice coupled with the application of bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} on 8 DAS (PE) fb metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS (PoE) fb hand weeding on 45 DAS recorded the lowest weed population, dry matter production and the highest weed control efficiency, grain yield and this were on par with manual wet seeded rice coupled with -pre-emergence application on 8 DAS FB -post-emergence application on 25 DAS fb hand weeding on 45 DAS. However, manual wet-seeded rice led to a higher cost of cultivation with less benefit-cost ratio hence, drum-seeded rice coupled with the application of -pre-emergence on 8 DAS fb application of -post-emergence on 25 DAS fb hand weeding on 45 DAS is an economically feasible method for effective control of weeds.

Future scope of the study

Future research may be focused on the development of solar based or mechanically operated drum seeder for sowing larger area in short period compared to the manual operated drum seeder. Drone spraying of new generation herbicides/nano herbicides may be developed for timely weed management in larger areas.

Acknowledgement: This study was conducted in partial requirement for PhD at Annamalai University, Chidambaram, Tamilnadu and the authors are thankful for the support provided by the Dean, Head of the department and all staffs of the Department of Agronomy.

Conflict of interest: The authors declare that is there is no conflict of interest.

Table 1. Weed dynamics as influenced by different direct seeded establishment methods and new generation herbicidal combinations in rice (Oryza sativa L.)

Treatments	Grass weed population (No. m^{-2})		Sedge weed population (No. m^{-2})		Broad-leaved weed population (No. m^{-2})		Total weed population at 60 DAS (No. m^{-2})		Total weed dry matter production at 60 DAS (g m^{-2})	
	At 30 DAS	At 60 DAS	At 30 DAS	At 60 DAS	At 30 DAS	At 60 DAS	At 30 DAS	At 60 DAS	At 30 DAS	At 60 DAS
M_1	4.52 (19.97)	8.92 (79.07)	3.48 (12.56)	7.24 (51.92)	2.79 (7.30)	6.56 (42.53)	6.35 (39.83)	13.19 (173.52)	2.72 (6.89)	10.13 (102.20)
M_2	4.15 (16.73)	7.12 (50.24)	3.17 (10.50)	5.77 (32.77)	2.57 (6.10)	5.23 (26.87)	5.82 (33.33)	10.51 (109.88)	2.44 (5.45)	8.04 (64.14)
M_3	4.16 (16.82)	7.13 (50.39)	3.18 (10.56)	5.78 (32.86)	2.58 (6.14)	5.24 (26.95)	5.83 (33.52)	10.52 (110.19)	2.45 (5.49)	8.05 (64.32)
S.Ed	**0.05**	**0.08**	**0.04**	**0.07**	**0.03**	**0.06**	**0.07**	**0.12**	**0.03**	**0.09**
CD (p=0.05)	**0.14**	**0.23**	**0.11**	**0.19**	**0.09**	**0.17**	**0.20**	**0.34**	**0.08**	**0.26**
S_1	7.36 (53.68)	11.86 (140.17)	5.90 (34.36)	9.44 (88.59)	4.45 (19.32)	8.54 (72.40)	10.39 (107.36)	17.37 (301.17)	4.33 (18.25)	13.33 (177.19)
S_2	3.72 (13.34)	6.38 (40.25)	2.93 (8.06)	5.10 (25.46)	2.36 (5.05)	4.61 (20.78)	5.19 (26.44)	9.33 (86.50)	2.20 (4.34)	7.10 (49.97)
S_3	4.15 (16.70)	8.07 (64.62)	3.35 (10.69)	6.65 (43.76)	2.55 (6.01)	6.02 (35.71)	5.82 (33.42)	12.02 (144.08)	2.49 (5.68)	9.25 (85.01)
S_4	4.16 (16.77)	8.13 (65.67)	3.35 (10.72)	6.71 (44.56)	2.56 (6.05)	6.06 (36.28)	5.84 (33.55)	12.13 (146.52)	2.49 (5.70)	9.32 (86.45)
S_5	4.16 (16.78)	8.17 (66.22)	3.36 (10.77)	6.74 (44.90)	2.56 (6.07)	6.09 (36.57)	5.84 (33.64)	12.17 (147.69)	2.49 (5.72)	9.36 (87.14)
S_6	3.26 (10.14)	6.95 (47.77)	2.58 (6.14)	5.61 (30.92)	2.06 (3.73)	5.12 (25 69)	4.53 (20.00)	10.24 (104.38)	1.92 (3.19)	7.84 (60.89)
S_7	3.48 (11.62)	7.55 (56.51)	2.76 (7.10)	6.10 (36.69)	2.21 (4.38)	5.57 (30.49)	4.86 (23.10)	11.14 (123.69)	2.07 (3.79)	8.54 (72.41)
S_8	3.25 (10.08)	5.16 (26.09)	2.56 (6.07)	4.17 (16.90)	2.04 (3.65)	3.81 (14.01)	4.51 (19.80)	7.58 (56.99)	1.89 (3.08)	5.76 (32.70)
S_9	3.46 (11.44)	5.68 (31.81)	2.73 (6.96)	4.62 (20.86)	2.19 (4.33)	4.19 (17.09)	4.82 (22.71)	8.38 (69.76)	2.06 (3.74)	6.38 (40.25)
S.Ed	**0.09**	**0.17**	**0.07**	**0.14**	**0.06**	**0.12**	**0.12**	**0.25**	**0.06**	**0.19**
CD (p=0.05)	**0.19**	**0.34**	**0.14**	**0.28**	**0.12**	**0.25**	**0.24**	**0.50**	**0.11**	**0.38**

Figures in the parentheses are original values, fb – followed by, HW – hand weeding, M_1-Dry seeded rice, M_2-Drum seeded rice, M_3-Manual wet seeded rice, S_1-Unweeded Control, S_2-Twice hand weeding on 25 and 45 DAS, S_3 - bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} on 8 DAS (PE) fb HW at 45 DAS, S_4– triafamone 20% + ethoxysulfuron 10% WG @ 200 g ha^{-1} on 12 DAS (EPoE) fb HW at 45 DAS, S_5– metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS (PoE) fb HW at 45 DAS, S_6- bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} on 8 DAS (PE) fb metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS (PoE), S_7 - triafamone 20% + ethoxysulfuron 10% WG @ 200 g ha^{-1} on 12 DAS (EPoE) fb metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS (PoE), S_8- bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} on 8 DAS (PE) fb Metsulfuron Methyl 10% + Chlorimuron Ethyl 10% @ 20 g ha^{-1} on 25 DAS (PoE) fb HW at 45 DAS and S_9 - triafamone 20% + ethoxysulfuron 10% WG @ 200 g ha^{-1} on 12 DAS (EPoE) fb metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS (PoE) fb HW at 45 DAS.

Table 2. Nutrient removal by weeds, grain yield and benefit cost ratio in rice as influenced by different direct seeded establishment methods and new generation herbicidal combinations

Treatments	Nutrient removal by weeds (kg ha^{-1})			Grain yield (kg ha^{-1})	Benefit-cost ratio
	Nitrogen	Phosphorus	Potassium		
M_1-Dry seeded rice	27.55	6.14	42.78	4087	1.76
M_2-Drum seeded rice	24.84	5.55	39.69	4824	2.22
M_3-Manual wet seeded rice	25.61	5.57	40.61	4725	1.95
S.Ed **C.D (p = 0.05)**	0.26 0.79	0.08 0.23	0.31 0.94	40.09 111.06	-- --
S_1 -Unweeded control	40.96	7.05	49.76	3293	1.59
S_2 -Twice hand weeding on 25 and 45 DAS	18.84	5.03	37.46	5091	2.09
S_3 - Bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} on 8 DAS (PE) fb HW at 45 DAS	31.39	6.45	43.92	4199	1.81
S_4 – Triafamone 20% + ethoxysulfuron 10% WG @ 200 g ha^{-1} on 12 DAS (EPoE) fb HW at 45 DAS	31.86	6.49	43.98	4131	1.77
S_5 – Metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS (PoE) fb HW at 45 DAS	32.08	6.52	44.02	4057	1.81
S_6 - Bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} on 8 DAS (PE) fb metsulfuron methyl 10 % + chlorimuron ethyl 10 % @ 20 g ha^{-1} on 25 DAS (PoE)	22.61	5.50	39.55	4725	2.12
S_7 - Triafamone 20% + ethoxysulfuron 10% WG @ 200 g ha^{-1} on 12 DAS (EPoE) fb metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS (PoE)	26.76	5.97	41.53	4427	1.97
S_8- Bensulfuron methyl 0.6% + pretilachlor 6% GR @ 10 kg ha^{-1} on 8 DAS (PE) fb metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS (PoE) fb HW at 45 DAS	13.53	4.17	33.53	5639	2.39
S_9 - Triafamone 20% + ethoxysulfuron 10% WG @ 200 g ha^{-1} on 12 DAS (EPoE) fb metsulfuron methyl 10% + chlorimuron ethyl 10% @ 20 g ha^{-1} on 25 DAS (PoE) fb HW at 45 DAS	15.96	4.60	35.48	5344	2.25
S.Ed **CD (p=0.05)**	0.66 1.32	0.20 0.41	0.90 1.82	98.19 197.44	-- --

fb – followed by, HW – hand weeding, PE – pre-emergence, EPoE – early post-emergence and PoE – post-emergence

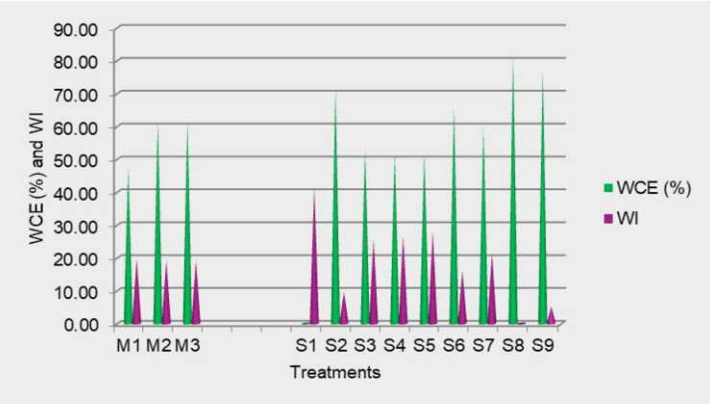

Figure 1. Weed control efficiency and weed index as influenced by different direct seeded establishment methods and new generation herbicidal combinations in rice (Oryza sativa L.)

References

1. DES. 2022. Agricultural Statistics at a Glance; Directorate of Economics and Statistics, Ministry of Agriculture, Cooperation and Farmers Welfare, Government of India: New Delhi, India, p. 24.

2. Bhandari S, Khanal S, Dhakal S (2020) Adoption of direct seeded rice (DSR) over puddled-transplanted rice (TPR) for resource conservation and increasing wheat yield. Reviews in Food and Agriculture 1: 44-51.

3. Suganya R (2022) Efficacy of new generation herbicidal combination for weed management in direct seeded rice (*Oryza sativa* L.). Ph.D. (Agri.) Thesis, Department of Agronomy, Annamalai University.

4. Sen S, Kaur R, Das TK, Shivay YS, Sahoo PM (2018) Bio efficacy of sequentially applied herbicides on weed competition and crop performance in dry direct-seeded rice (*Oryza sativa*). Indian J Agron 63: 230–233.

5. Arunbabu T, Jena SN 2018. Weeds and progressive weed management techniques in rice (*Oryza sativa*. L.): A review. Bull Env Pharmacol Life Sci 7:108-117.

6. Sen S, Kaur R, Das TK (2020) Weed management in dry direct-seeded rice: Assessing the impacts on weeds and crop. Indian J Weed Sci 52: 169-174.

7. Mani VS, Malla ML, Gautam KC, Das B (1973) Weed killing chemicals in potato cultivation. PANS 23: 17-18.

8. Abhishek GM, Thimmegowda MN, Ramachandrappa BK, Nagaraju, Murukannappa (2017) Efficiency of herbigation based weed management practices in aerobic rice. Int J Sci Nat 8: 447-452.

9. Kashid NV, Barhate KK, Bodake PS (2015) Management of weeds in direct-seeded rice. Indian J Weed Sci 47: 110-112.

10. Sanjay Kumar, Pandey N, Ajit Kumar, Singh AK, Tarun Gopal, Dinesh Kumar (2018) Effect of establishment methods and weed management practices on economics of direct seeded rice (*Oryza sativa* L.). Int J Curr Microbiol App Sci 7: 1473-1480.

11. Nandan R, Singh V, Singh SS, Kumar V, Hazra KK, Nath CP (2018) Comparative assessment of the relative proportion of weed morphology, diversity, and growth under new generation tillage and crop establishment techniques in rice-based cropping systems. Crop Prot 111: 23-32.

12. Nayak BR, Manjappa K (2012) Documentation of existing cultivation practices followed in rice in hill region of Uttara Kannada district. Karnataka J Agric Sci 25: 397-402.

13. Netam CR, Netam AR, Qureshi K, Banjare, Netam AK (2018) Influence of various weed management approaches on weed dynamics in rice under different crop establishment methods. Int J Curr Microbiol App Sci 7: 1551-1557.

14. Yadav RI, Singh MK, Singh RK, Nagargade M (2018) Planting methods and weed management to improve yield in dry seeded rice. Indian J Weed Sci 50: 22-26.

15. Karthika R, Subramanian E, Ragavan T, Kumutha K (2019) Studies on crop weed competition and weed management in direct seeded rice under puddled and unpuddled conditions. Int J Chem Stud 7: 2769-2773.

16. Madhukumar V, Murthy KN, Sanjay MT, Prashanth R, Sunil CM (2013) Economics and crop weed competition for nutrients in aerobic rice (*Oryza sativa* L.) as influenced by weed control practices. Plant Archives 13: 731-734.

17. Patel TU, Vihol KJ, Thanki JD, Gudaghe NN, Desai LJ (2018) Weed and nitrogen management in direct-seeded rice. Indian J Weed Sci 50: 320-323.

18. Naz S, Nandan R, Roy DK (2020) Effect of crop establishment methods and weed management practices on productivity, economics and nutrient uptake in direct seeded rice (*Oryza sativa* L.). Int J Curr Microbiol App Sci 9: 3002-3009.

19. Dhaliwal SS, Sharma S, Shukla AK, Sharma V, Bhullar MS, Dhaliwal TK, et al. (2021) Removal of biomass and nutrients by weeds and direct-seeded rice under conservation agriculture in light-textured soils of North-Western India. Plants 10: 2431.

20. Parameswari YS, Srinivas A (2014) Influence of weed management practices on nutrient uptake and productivity of rice under different methods of crop establishment. J Rice Res 7: 77-86.

21. Reddy MSSK, Ameena M, (2021) Influence of weed management practices on weed flora, crop yield and nutrient uptake in direct seeded rainfed lowland rice. J Crop Weed 17: 206-210.

22. Malemnganbi T, Lhungdim J (2019) Influence of different doses of pyrazosulfuron-ethyl and establishment methods on the yield of lowland rice (*Oryza sativa* L.) J Crop Weed 15: 209-212.

23. Reddy MBG, Ravishankar G, Balganvi S, Joshi VR, Negalur RK (2012) Efficacy of bensulfuron methyl plus pretilachlor for controlling weeds in transplanted rice. Oryza 49: 65-67.
    Singh A, Pandey IB (2019) Effect of crop establishment methods, nutrient levels and weed management on yield of hybrid rice. J Pharmacogn Phytochem 8: 91-95.

