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Sivakumar C

Associate Professor, Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Vazhavachanur, Thiruvannamalai, Tamil Nadu, India

A Krishnaveni

Assistant Professor, Department of Environmental Sciences, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Vazhavachanur, Thiruvannamalai, Tamil Nadu, India

M Pandiyan

Dean, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Vazhavachanur, Thiruvannamalai, Tamil Nadu, India

Corresponding Author:**Sivakumar C**

Associate Professor, Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Vazhavachanur, Thiruvannamalai, Tamil Nadu, India

Efficiency of pre and post emergence herbicides with mechanical weeding on direct seeded rice in north western zone of Tamil Nadu

Sivakumar C, A Krishnaveni and M Pandiyan

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Abstract

The field experiments were conducted to study the effect of pre and post emergence herbicide with mechanical weeding on growth and yield of direct-seeded rice (DSR) at Regional Research Station, Tamil Nadu Agricultural University, Paiyur, Tamil Nadu, India in Navarai seasons of 2015 - 2016 and 2016 - 2017 in randomized block design with three replications. The weed management practices, viz. PE Application of Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ (T₁) at 2 - 3 leaf stage of weed recorded higher grain and straw yield of 5702 and 6047 kg ha⁻¹ respectively followed by PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ at 7 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ recorded grain and straw yield of 5531 and 5865 kg ha⁻¹ respectively. Control (Unweeded check) recorded lower grain and straw yield of 4149 and 4614 kg ha⁻¹ respectively. With respect to economic analysis, application of PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ (T₁) recorded higher gross income of Rs. 83218, net income of Rs. 47657 with the BC ratio of 2.33 followed by PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ at 7 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed recorded gross income of Rs. 80703, net income of Rs. 44970 with the BC ratio of 2.25. Control (Unweeded check) recorded lower gross income of Rs. 60808, net income of Rs. 30254 with the BC ratio of 1.98 The crop growth parameters like germination (%), plant height and no. of tillers and yield attributes (no. of panicle (m⁻²), Panicle length (cm), no. of grains panicle⁻¹, no. of in filled grains panicle⁻¹, test weight(g), grain yield (kg ha⁻¹) and straw yield (kg ha⁻¹) were also highest in this weed management practice.

Keywords: Cono weeder, drum seeding, bispyribac sodium, pyrazosulfuron ethyl, mechanical weeding

Introduction

Paddy (*Oryza sativa* L.) seeds sown through direct (drum) seeding (DSR) is an ecofriendly water and energy (labor) saving method for the present resources scarcity scenario apart from the problem of weed diversity and density at the early stage of crop growth and development. There were many reports on reduction of yield by 50-60% in direct seeded rice. Even in certain reports, the reduction of yield of the rice crop due to weeds has been extended up to 95% in India (Naresh *et al.* 2011), 71-96% in the Philippines (Chauhan and Johnson 2011) and 33-80% in Pakistan (Khaliq *et al.*). The practice of wet seeding mainly depends on availability of efficient weed management practices because uncontrolled weeds in direct wet seeded rice can reduce yields to the tune of 53 percent (Nyarko and Datta, 1991) ^[1] and losses were reported even up to 90 per cent (Bhat *et. al.*, 2011) ^[2]. To manage the yield loss in this direct seeding method, timely weeding is inevitable at the initial crop stage to get economic yield. Though, there are many methods are available to control the weeds competing with crop for the nutrients and space. But, some of the methods like manual weeding are not possible at critical crop growth stages due to scarcity of labour, time consuming and cost. In this critical condition, pre and post emergence herbicides have been another and timely alternative to manual weeding in DSR rice (Choudhary 2017, Choudhary *et al.* 2017). It has several advantages such as 35-57% less water requirement and 67% less labour involved when compared to common establishment technique like seedling and transplantation. In addition, DSR requires less machine usage and lesser methane emission (Chauhan *et al.* 2012). Nowadays, direct rice seeding by drum seeder was adopted by many farmers in this north

western agro climatic zone of Tamil Nadu. There is common fear among the rice farmers like weed menace, improper knowledge in herbicides usage, herbicidal phytotoxicity, lack of spraying skill at the initial critical stage which leads to yield loss in the DSR technology. There are many recommended herbicides are available for weed management in DSR. However, the efficacy of pre and post emergence herbicides can vary from molecule to molecule based on the operating environmental condition (Mahajan and Chauhan 2013). Hence, farmers of this region need proper pre and post emergence herbicides having higher weed controlling efficiency with non-phototoxic properties to adopt DSR technique without fear. Direct seeded rice offers the advantage of faster and easier planting, ensure proper plant population, reduce labour and hence less drudgery, 10-12 days earlier crop maturity, more efficient water use and higher tolerance to water-deficit, and often high profit in areas with assured water supply (De Datta, 1986) [11]. The weed flora of wet seeded rice crop is entirely different from that of transplanted crop due to maintenance of saturation moisture at sowing and shallow depths of water up to 3 weeks after sowing. As weeds emerge almost at the same time as that of the crop in wet seeded rice and weed competition with rice crop is greater, hence weed management by herbicide is more crucial. Based on the above issues, the research has been conducted in this north western agro climatic zone of Tamil Nadu to study the weed controlling efficiency of different pre and post emergence herbicide along with mechanical weeding under direct wet seeded rice crop sown through drum seeder.

Materials and Methods

The field experiments were conducted to study the effect of pre and post emergence herbicide with mechanical weeding on weed management in drum seeded rice (DSR) at Regional Research Station, Tamil Nadu Agricultural University, Paiyur 635 112, Tamil Nadu, India in Navarai seasons of 2015 - 2016 and 2016 - 2017 respectively in randomized block design with three replications. The eight row drum seeder (20 cm line spacing) was used and the test variety was ADT 39 with 135 days duration. The scheduled time for pre emergence herbicides were; pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ was applied at 3 DAS, Pendimethalin 38.7% CS @ 0.65 kg ha⁻¹ was applied at 6 DAS and Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ (tank mix) was applied at 7 DAS and post emergence herbicide; Bispyribac sodium 10% EC @ 25 g ha⁻¹ applied at 2 - 3 leaf stage of weed. Pre-germinated seed @ 25 kg ha⁻¹ was used for wet drum seeding of rice. Pre-emergence and post-emergence herbicides were applied with the help of a sand mixture and hand-operated knapsack sprayer fitted with flat-fan nozzle respectively and water as a carrier at 600 liters ha⁻¹ for post emergent herbicide application. Observations on weed population and weed dry matter were recorded with the help of a quadrat 1 m × 1 m placed randomly at two spots in each plot at 30, 60 and 90 DAS and expressed in number per meter square (No. m⁻²) and gram per meter square (g m⁻²) respectively. The data was subjected to square root transformation to normalize their distribution and statistical analysis was done as suggested by Gomez and Gomez (1984) [4]. Weed control efficiency was calculated according to Mani *et al.* (1973) [14] as per the standard formulae by using weed dry matter at 30, 60 and 90 DAS. The biometric observations for rice crop were recorded as per the guidelines given by the All India Co-Ordinated Rice Improvement Project (Haveten,

1997) The yield parameter like no. of panicle (m⁻²), panicle length (cm), no. of grains panicle⁻¹, no. of infilled grains panicle⁻¹ were calculated from the individual plots were taken and converted to kg per hectare. and calculated the economics of DSR to know the feasibility of this DSR technique.

Treatments details

- T₁ PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed
- T₂ PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ at 3 DAS (tankmix) at 7 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed
- T₃ PE Pendimethalin 38.7% CS @ 0.65 kg ha⁻¹ 6 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed
- T₄ PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ 3 DAS + Mechanical weeding (Cono weeder) at 30 DAS
- T₅ PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ (tankmix) at 7 DAS + Mechanical weeding (Cono weeder) at 30 DAS
- T₆ PE Pendimethalin 38.7% CS @ 0.65 kg ha⁻¹ 6 DAS + Mechanical weeding (Cono weeder) at 30 DAS
- T₇ Mechanical weeding (Cono weeder) at 15 and 30 DAS
- T₈ Hand weeding twice at 15 and 30 DAS
- T₉ Control (Unweeded check)

Results and Discussion

Weed flora

The dominant weed flora of the experimental fields are *Echinochola colona* among the grasses, *Cyperus difformis* among the sedges and *Ammannia baccifera*, *Bergia capensis*, *Marsilia quadrifolia*, *Eclipta alba* among the Broad Leaved Weeds (BLW).

Characteristic of Weed

Weed density at 30 DAS

The dry weight and weed control efficiency were worked out at 30 DAS. Application of PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed (T₁) recorded lower weed density of 1.2 and 2.5 m⁻² in first and second season respectively at 30 DAS followed by PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ 3 DAS + Mechanical weeding (Cono weeder) at 30 DAS recorded 1.4 m⁻² (T₄). Control (Unweeded check) recorded higher weed density of 719.7 and 900 m⁻² (Table 1).

Weed dry weight (WDW)

The application of PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ (T₁) at 2 - 3 leaf stage of weed recorded lower weed dry weight of 0.1 g m⁻² at 30 DAS followed by PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ 3 DAS + Mechanical weeding (Cono weeder) at 30 DAS recorded 0.3 g m⁻² (T₄). Control (Unweeded check) recorded higher weed density of 5.2 g m⁻² (T₉) in 2015. Pretilachlor + safener @ 0.4 kg a.i ha⁻¹ at 3 days after seeding + hand weeding at 40 DAS and two hand weeding at 20 and 40 DAS (T₃) has recorded crop dry matter production (104 and 851.94 gm⁻² respectively) and number of tillers per meter square (424 and 499 respectively) which may be due to broad spectrum of weed control, less weed competition throughout crop growth period and selectivity to rice crop (Sangeetha, 2006) [19].

Weed control efficiency (WCE)

The application of PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ (T₁) at 2 - 3 leaf stage of weed recorded higher WCE of 98.0% at 30 DAS followed by PE Pyrazosulfuron ethyl 10%

WP @ 20 g ha⁻¹ 3 DAS + Mechanical weeding (Cono weeder) at 30 DAS recorded 94.0% (T₄) in 2015. Weed density, dry weight and weed control efficiency were worked out at 30 DAS in 2016 similar to 2015 trend but slight variation in the values.

Table 1: Effect of weed control treatments on weed density (Nos.), weed dry weight (WDW) and weed control efficiency (WCE) of direct seeded rice at 30 DAS (2015 - 2016)

Treatments	Weed density at 30 DAS (No.m ⁻²)								WDW at 30 DAS (g m ⁻²)		WCE (%)	
	Grasses		BLW		Sedges		Total		2015	2016	2015	2016
	2015	2016	2015	2016	2015	2016	2015	2016				
T ₁	0.7 (0.5)	2.5 (6.7)	0.7 (0.5)	0.7 (0.0)	1.2 (1.3)	0.7 (0.0)	1.2 (1.3)	2.5 (6.7)	0.8 (0.1)	1.6 (1.9)	98.0	85
T ₂	2.1 (7.7)	3.0 (11.3)	2.4 (10.7)	0.7 (0.0)	3.4 (25.3)	0.7 (0.0)	4.3 (43.6)	3.0 (11.3)	1.4 (1.6)	2.0 (3.4)	69.0	73
T ₃	1.2 (1.7)	4.3 (18.7)	7.8 (93.3)	2.7 (10.0)	12.3 (218.3)	4.0 (27.3)	14.6 (313.3)	7.1 (56.0)	1.7 (2.3)	2.4 (5.3)	56.0	58
T ₄	0.7 (0.5)	3.5 (16.3)	0.7 (0.5)	4.4 (27.3)	1.4 (2.3)	2.6 (13.7)	1.4 (2.3)	6.1 (57.3)	0.8 (0.3)	2.3 (5.2)	94.0	59
T ₅	2.1 (8.3)	3.4 (11.7)	0.7 (0.5)	3.3 (14.7)	1.5 (3.3)	1.2 (1.3)	2.9 (11.6)	5.0 (27.7)	0.9 (0.4)	2.1 (3.9)	94.0	69
T ₆	1.9 (4.3)	4.7 (27.3)	5.1 (39.0)	5.1 (64.3)	9.2 (130.0)	7.4 (145.3)	10.5 (173.3)	10.8 (237.0)	1.9 (3.9)	2.3 (5.1)	25.0	60
T ₇	1.9 (4.0)	4.5 (29.0)	6.5 (60.7)	10.1 (115.0)	6.5 (60.0)	6.8 (65.0)	9.3 (124.7)	13.5 (209.0)	2.0 (3.8)	2.5 (6.3)	27.0	50
T ₈	3.6 (13.3)	5.0 (34.3)	9.4 (90.3)	14.7 (221.3)	7.9 (64.3)	12.1 (149.3)	12.8 (168.0)	19.8 (405.0)	2.0 (3.5)	2.6 (6.2)	48.6	51
T ₉	4.2 (17.3)	6.3 (41.7)	17.6 (331)	22.6 (518.0)	18.4 (371.0)	17.6 (340.3)	25.8 (719.7)	29.6 (900.0)	2.3 (5.2)	3.5 (12.7)	-	-
SED	1.1	1.8	3.3	1.8	4.7	1.9	5.8	2.2	0.6	0.5	-	-
CD (P=0.05)	2.4	3.9	7.1	3.9	9.9	3.9	12.3	4.7	1.3	1.1	-	-

T₁.PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed, T₂.PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ at 3 DAS (tankmix) at 7 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed, T₃.PE Pendimethalin 38.7% EC @ 0.65 kg ha⁻¹ 6 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed, T₄.PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ 3 DAS + Mechanical weeding (Cono weeder) at 30 DAS, T₅.PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ (tankmix) at 7 DAS + Mechanical weeding (Cono weeder) at 30 DAS, T₆.PE Pendimethalin 38.7% CS @ 0.65 kg ha⁻¹ 6 DAS + Mechanical weeding (Cono weeder) at 30 DAS, T₇.Mechanical weeding (Cono weeder) at 15 and 30 DAS, T₈.Hand weeding twice at 15 and 30 DAS, T₉.Control (Unweeded check)

Figures in parenthesis are original values (Analysis by $\sqrt{x+0.5}$ transformations)

Weed density at 60 DAS

The application of PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ (T₁) recorded lower weed density of 2.3 m⁻² at 60 DAS followed by PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ 3 DAS + Mechanical weeding (Cono weeder) at 60 DAS recorded 11.7 m⁻² (T₄). Control (unweeded check) recorded higher weed density of 486.7 m⁻². Severe weed competition exerted by weeds for the available resources throughout the crop growth period might have lowered the plant height, dry matter production and number of tillers under unweeded check. Similar result was also reported by Porpavai *et al.* (2006) [14].

The maximum weed dry matter reduction was achieved due to application of PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ (T₁) recorded lower weed dry weight of 1.6 g m⁻² at 60 DAS followed by PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ 3 DAS + mechanical weeding (cono weeder) at 60 DAS recorded 2.5 g m⁻² (T₄). Control (unweeded check) recorded higher weed density of 80.9 g m⁻² (T₉). The result was similar to that the dry matter reduction was achieved due to herbicide as pre-emergence supplemented with two hand weeding in wet seeded rice (Singh, *et al.*, 2006) [28].

Weed control efficiency (WCE)

The application of PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ (T₁) recorded higher weed control efficiency of 98% at 60 DAS followed by PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ at 7 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ recorded weed control efficiency of 96% (T₂) during 2015. Highest weed control efficiency (88%) was obtained from the treatment receiving pretilachlor 0.75 kg ha⁻¹ with paddy weeder at 40 DAT (Rajkhowa). Pretilachlor + safener @ 0.4 kg a.i ha⁻¹ at 3 days after seeding + hand weeding at 40 DAS and two hand weeding at 20 and 40 DAS (T₃) has recorded crop dry matter production (104 and 851.94 gm⁻² respectively) and number of tillers per meter square (424 and 499 respectively) which may be due to broad spectrum of weed control, less weed competition throughout crop growth period and selectivity to rice crop (Sangeetha, 2006) [19]. Similar result was also observed by Narendra (2011), Subhash Babu *et al.* (2008) [28] and Ramana *et al.* (2007) [17]. Weed density, dry weight and weed control efficiency were worked out at 60 DAS in 2016 similar to 2015 trend but slight variation in the values.

Table 2: Effect of weed control treatments on weed density (Nos) and weed dry weight (WDW) of direct seeded rice at 60 DAS (2015 - 2016)

Treatments	Weed density at 60 DAS (No.m ⁻²)								WDW at 60 DAS (g m ⁻²)		WCE (%)	
	Grasses		BLW		Sedges		Total		2015	2016	2015	2016
	2015	2016	2015	2016	2015	2016	2015	2016				
T ₁	1.0 (0.6)	2.9 (12.3)	0.9 (0.7)	0.7 (0.0)	1.1 (1.0)	0.7 (0.0)	1.4 (2.3)	2.9 (12.3)	0.8 (1.6)	0.9 (0.9)	98.0	85
T ₂	3.0 (19.7)	3.7 (19.0)	2.4 (10.7)	0.7 (0.0)	1.8 (5.7)	0.7 (0.0)	3.9 (36.0)	3.7 (19.0)	1.2 (2.6)	1.7 (2.6)	96.0	73
T ₃	2.1 (5.0)	5.4 (30.3)	7.1 (71.7)	0.7 (0.0)	7.9 (90.0)	0.7 (0.0)	12.3 (154.7)	5.4 (30.3)	4.4 (28.7)	4.3 (28.7)	64.5	58
T ₄	1.9 (5.7)	5.1 (30.0)	1.7 (4.7)	3.9 (21.3)	1.2 (1.3)	4.6 (30.3)	3.4 (11.7)	8.1 (81.7)	1.0 (2.5)	3.9 (14.9)	97.0	59
T ₅	1.7 (3.3)	4.0 (22.7)	3.4 (25.3)	12.5 (218.3)	6.0 (81.7)	5.3 (29.3)	7.7 (66.0)	15.6 (270.3)	5.3 (28.8)	5.4 (28.8)	64.4	69
T ₆	3.3 (1.7)	4.8 (28.3)	9.5 (96.3)	7.6 (74.7)	7.6 (81.7)	9.1 (127.7)	12.6 (179.7)	15.0 (230.7)	3.4 (15.9)	5.2 (27.0)	80.3	60
T ₇	3.4 (11.3)	6.4 (42.7)	13.0 (220)	8.6 (76.3)	8.9 (110)	9.6 (99.0)	16.3 (341.0)	14.6 (218.0)	7.2 (61.7)	7.2 (61.7)	23.7	50
T ₈	4.4 (23.0)	5.8 (36.7)	14.8 (220)	13.0 (183.0)	9.2 (97)	11.3 (135.0)	18.3 (340.1)	18.5 (354.7)	6.5 (45.8)	6.5 (45.8)	43.0	51

T ₉	3.2 (13.0)	5.9 (46)	15.6 (284)	33.7 (1157)	13.2 (189.7)	19.2 (424)	20.9 (486.7)	39.8 (1628)	9.1 (80.9)	8.2 (80.9)	-	-
SEd	1.8	1.8	3.8	2.2	3.7	1.8	4.4	3.2	2.3	0.9	-	-
CD (p=0.05)	3.8	3.9	7.9	4.7	7.8	3.9	9.2	6.6	4.8	2.0	-	-

T₁.PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS +POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed, T₂.PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ at 3 DAS (tankmix) at 7 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed, T₃.PE Pendimethalin 38.7% EC @ 0.65 kg ha⁻¹ 6 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed, T₄.PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ 3 DAS + Mechanical weeding (Cono weeder) at 30 DAS, T₅.PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ (tankmix) at 7 DAS+ Mechanical weeding (Cono weeder) at 30 DAS, T₆.PE Pendimethalin 38.7% CS @ 0.65 kg ha⁻¹ 6 DAS + Mechanical weeding (Cono weeder) at 30 DAS, T₇.Mechanical weeding (Cono weeder) at 15 and 30 DAS, T₈.Hand weeding twice at 15 and 30 DAS, T₉.Control (Unweeded check)

Figures in parenthesis are original values (Analysis by $\sqrt{x+0.5}$ transformations)

Growth characters

Growth parameters like plant height and no. of tillers were recorded at 30, 60 90 DAS. The Germination (%) and Herbicide toxicity were recorded at different crop intervals.

Plant height

The application of PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS +POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ (T₁) recorded higher plant height of 20.1,52.8 and 88.2 (81.6 cm) cm at 30,60,90 DAS followed by PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ 3 DAS + Mechanical weeding (Cono weeder) at 30 DAS recorded 19.9,50.2 80.1 and 86.7 cm at 30,60,90 DAS respectively (T₂). Control (Unweeded check) recorded lower plant height of 18.4, 44.6, 75.0 at 30, 60 90 DAS respectively. Pretilachlor + safener @ 0.4 kg a.i ha⁻¹ at 3 days after seeding+ hand weeding at 40 DAS and two hand weeding at 20 and 40 DAS next to weed free check (Plant height (73.50 and 96.68 cm respectively),

No. of tillers

The application of PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS +POE Bispyribac sodium 10% EC @ 25 g ha⁻¹

(T₁) recorded higher tiller number of 354 at 90 DAS followed by PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ 3 DAS + Mechanical weeding (Cono weeder) at 30 DAS recorded tiller number of 346 at 90 DAS (T₄). Control (Unweeded check) recorded lower tiller number of 280 at 90 DAS during 2016.Pretilachlor + safener @ 0.4 kg a.i ha⁻¹ at 3 days after seeding+ hand weeding at 40 DAS and two hand weeding at 20 and 40 DAS (T₃) has recorded crop dry matter production (104 and 851.94 gm⁻² respectively) and number of tillers per meter square (424 and 499 respectively) which may be due to broad spectrum of weed control, less weed competition throughout crop growth period and selectivity to rice crop (Sangeetha, 2006)^[19].

Herbicide toxicity and germination (%) of crop

Pre emergence application of Pendimethalin 38.7% CS @ 0.65 kg ha⁻¹ at 6 DAS exhibits phytotoxic on crop plants with the herbicide classification scoring is 2 on 30 DAS.. For confirmation, soil was taken in herbicide applied plot where the crop injury exhibited and cucumber crop was raised in pot culture. 100% germination was recorded in pot culture experiment.

Table 3: Effect of weed control treatments on growth characters of direct (drum) seeded rice (2015-2016)

Treatments	Plant height (cm)						Herbicide toxicity for crop on 30 DAS		Germination (%)		No. of tillers (m ⁻²) on 90 DAS	
	30 DAS		60 DAS		90 DAS		2015	2016	30 DAS		2015	2016
	2015	2016	2015	2016	2015	2016			2015	2016		
T ₁	20.1	20.6	52.8	53.5	81.6	75.2	0	0	100	100	354	359.3
T ₂	18.6	19.1	47.3	52.5	77.8	74.8	0	0	100	100	350	352.7
T ₃	18.9	19.4	48.1	49.4	76.2	73.1	2	2	100	100	339	344.7
T ₄	19.9	20.4	50.2	49.2	80.1	74.2	0	0	100	100	346	356.0
T ₅	18.7	19.2	46.4	50.9	78.8	74.3	0	0	100	100	358	354.3
T ₆	18.8	19.3	44.9	50.2	80.8	74.0	2	2	100	100	346	350.7
T ₇	18.7	19.2	45.8	47.9	79.2	71.5	-	-	-	-	340	343.0
T ₈	19.0	19.5	48.2	47.6	78.9	72.8	-	-	100	100	341	340.0
T ₉	18.4	18.9	44.6	46.5	75.0	71.5	-	-	-	-	280	326.7
SEd	1.6	1.6	2.4	0.9	2.8	1.6	-	-	-	-	6.8	6.9
CD (P=0.05)	3.3	3.4	5.0	1.9	6.1	3.4	-	-	-	-	13.2	14.6

T₁.PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS +POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed, T₂.PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ at 3 DAS (tankmix) at 7 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed, T₃.PE Pendimethalin 38.7% EC @ 0.65 kg ha⁻¹ 6 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed, T₄.PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ 3 DAS + Mechanical weeding (Cono weeder) at 30 DAS, T₅.PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ (tankmix) at 7 DAS+ Mechanical weeding (Cono weeder) at 30 DAS, T₆.PE Pendimethalin 38.7% CS @ 0.65 kg ha⁻¹ 6 DAS + Mechanical weeding (Cono weeder) at 30 DAS, T₇.Mechanical weeding (Cono weeder) at 15 and 30 DAS, T₈.Hand weeding twice at 15 and 30 DAS, T₉.Control (Unweeded check)

Herbicide toxicity classification

0	No injury	7-9	Severe injury
1-3	Less injury	10	All plants killed
4-6	Moderately injured		

Weed index and yield parameters

The weed Index (%) and the yield parameters like no. of panicle (m⁻²), panicle length (cm), no. of grains panicle⁻¹ and

no. of unfilled grains panicle⁻¹, for different weed control treatments were recorded.

Weed index

The Control (Unweeded check) recorded higher weed index of 26.8%. (2015) and 27.7% (2016) whereas application of PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS +POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed had shown zero weed index value.

Yield parameters

Application of PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS +POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ (T₁) recorded higher number of panicle of 324.8, panicle length 22.4 cm. number of grains panicle of 154.1 and test weight of 16.1 g at harvesting stage followed by PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ at 7 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ recorded number of panicle of 324.0, panicle length 22.3 cm, number of grains panicle of 145.7 and test weight of 15.7 g at harvesting stage. Control (Unweeded check) recorded lower number of panicle of 255.8, panicle length of 21.6 cm, number of grains panicle of 126.4 and test weight of 14.2 g at harvesting stage during 2015.

Among the weed control treatments, the highest yield attributes viz., number of panicles per meter square (489), panicle length (21.28 cm) and number of grains per panicle (103) were recorded with bispyribac sodium 25 DAS @ 25 g a.i ha⁻¹ as PoE (T₆) fb cyhalofop-butyl @ 100 g a.i ha⁻¹ + (Chlorimuron-ethyl + metsulfuron-methyl) @ 4g a.i ha⁻¹ as a tank mixture (T₇). Application of PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS +POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ (T₁) recorded higher number of panicle of 349, panicle length 22.5 cm, number of grains panicle of 190 and test weight of 16.0 g at harvesting stage followed by PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ at 7 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ recorded number of panicle of 345, panicle length 22.4 cm, number of grains panicle of 180 and test weight of 15.4 g at harvesting stage. Control (Unweeded check) recorded lower number of panicle of 273, panicle length of 21.7 cm, number of grains panicle of 151 and test weight of 14.3 g at harvesting stage during 2016. The yield

attributes viz. number of panicles per meter square (497), panicle length (21.59 cm) and number of grains per panicle (107) were recorded highest in weed free check, which is mainly due to the lowest weed dry weight and highest weed control efficiency.

Yield and economics

The pooled analysis was done for the yield obtained during 2015 and 2016. The result indicated that all the weed control treatments brought out a significant effect on grain and straw yield of direct seeded rice as compared to unweeded check (Table 4). The highest grain yield and straw yield were recorded in application of PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS +POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ (T₁) recorded higher grain and straw yield of 5702 and 6047 kg ha⁻¹ respectively followed by PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ at 7 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ recorded grain and straw yield of 5531 and 5865 kg ha⁻¹ respectively and which was on par with T₁. The control (unweeded check) recorded lower grain and straw yield of 4149 and 4614 kg ha⁻¹ respectively due crop and weed competition at all the critical stages of the crops stressed the crop for the production of minimum number of panicles.

The maximum grain and straw yield were mainly due to the application of proper herbicides at right crop state resulted in lesser weeds competition for nutrients and light in the field which in turn reduced the weed flora, and density with improved weed control efficiency, which ultimately increased the crop dry matter with more number of panicles over unweeded check (T₉). The result indicated that all the adopted weed control treatments shown significant effect on yield of direct wet seeded rice as compared to unweeded check (Table 3). The significantly highest grain yield and straw yield were recorded in weed free (5800 and 7000 kg ha⁻¹ respectively) treatment (T₁). The findings were in agreement with the earlier reports of Veeraputhiarn and Balasubramanian (2010)^[16], Narendra (2011), Kumaran (2012)^[7], Porpavai *et al.* (2006)^[14] and Ramesh and Veerabadran (1997)^[18].

Table 4: Effect of different weed control treatments on yield and yield attributes of drum seeded rice (2015 - 2016) at harvesting stage

Treatments	Weed index (%)		No. of panicle (m ⁻²)		Panicle length (cm)		No. of grains panicle ⁻¹		No. of unfilled grains panicle ⁻¹	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
T ₁	-	-	324.8	349	22.4	22.5	154.1	190	12.9	18.2
T ₂	3.7	2.4	324.0	345	22.3	22.4	145.7	180	13.9	18.5
T ₃	9.5	9.4	319.0	334	22.2	22.1	132.4	176	14.7	20.9
T ₄	7.5	5.8	318.3	341	21.9	22.2	135.5	177	15.7	19.5
T ₅	7.4	7.5	320.2	353	22.3	22.4	141.0	178	14.3	18.8
T ₆	12.3	10.6	314.5	341	22.0	22.0	122.9	173	14.5	23.6
T ₇	13.4	17.0	297.5	332	22.1	21.7	127.4	153	13.8	24.6
T ₈	12.9	16.6	313.8	335	22.2	21.8	128.4	160	18.3	23.6
T ₉	26.8	27.7	255.8	273	21.6	21.7	126.4	151	20.2	33.6
SEd	-	-	20.7	9.0	0.3	0.3	6.2	7.4	0.7	3.5
CD(P=0.05)	-	-	43.4	18.0	0.7	0.7	13.0	15.5	1.4	7.4

T₁.PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS +POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed, T₂.PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ at 3 DAS (tankmix) at 7 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed, T₃.PE Pendimethalin 38.7% EC @ 0.65 kg ha⁻¹ 6 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed, T₄.PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ 3 DAS + Mechanical weeding (Cono weeder) at 30 DAS, T₅.PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ (tankmix) at 7 DAS+ Mechanical weeding (Cono weeder) at 30 DAS, T₆.PE Pendimethalin 38.7% CS @ 0.65 kg ha⁻¹ 6 DAS + Mechanical weeding (Cono weeder) at 30 DAS, T₇.Mechanical weeding (Cono weeder) at 15 and 30 DAS, T₈.Hand weeding twice at 15 and 30 DAS, T₉.Control (Unweeded check)

Significantly lower grain (3467 kg ha⁻¹) and straw yield (4526 kg ha⁻¹) were observed in metamifop (100 g a.i ha⁻¹ at 3rd leaf stage) as PoE (T₄). Accordingly, Subramanian,

(2002)^[16] stated that the pre-sowing application of glyphosate + pre-emergence application of pretilachlor (with safener) followed by two manual weedings effectively controlled a

wide spectrum of weeds, and recorded a maximum grain yield of 5872 kg ha⁻¹. Higher grain and straw yield were reported when pretilachlor + safener (0.4 kg a.i ha⁻¹ at 3 days after seeding) as PE (T5) was applied. The reduction in grain and straw yield in these treatments along with unweeded check (2378 and 3500 kg ha⁻¹) was mainly due to decrease in growth and yield components of rice under increased pressure of weed competition for space, light, nutrients and these results were in accordance with Sangeetha (2006) [19] and Singh and Pairka (2014) [28]. With respect to economic analysis, application of PE Pyrazosulfuron ethyl 10% WP @

20 g ha⁻¹ at 3 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ (T₁) recorded higher gross income of Rs. 83218, net income of Rs. 47657 with the BC ratio of 2.33 followed by PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ at 7 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ recorded gross income of Rs. 80703, net income of Rs. 44970 with the BC ratio of 2.25. Control (Unweeded check) recorded lower gross income of Rs. 60808, net income of Rs. 30254 with the BC ratio of 1.98 (Table 5)

Table 5: Pooled analysis on effect of different weed control treatments on drum seeded rice (2016-2017)

Treatments	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Gross income (Rs)	Cost of cultivation (Rs ha ⁻¹)	Net income (Rs)	B:C ratio
T ₁	5702	6047	83218	34560	47657	2.33
T ₂	5531	5865	80703	34735	44970	2.25
T ₃	5189	5502	75703	34875	39829	2.11
T ₄	5327	5648	77715	35560	41154	2.12
T ₅	5294	5613	77258	35735	40522	2.10
T ₆	5054	5359	73737	34875	37860	2.06
T ₇	4824	5114	70380	33760	33814	2.03
T ₈	4859	5151	70884	33010	34679	2.08
T ₉	4149	4614	60808	29760	30254	1.98
SEd	181	187	-	-	-	-
CD (P=0.05)	381	392	-	-	-	-

T₁.PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS +POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed, T₂. PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ at 3 DAS (tankmix) at 7 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed, T₃.PE Pendimethalin 38.7% EC @ 0.65 kg ha⁻¹ 6 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed, T₄.PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ 3 DAS + Mechanical weeding (Cono weeder) at 30 DAS, T₅. PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ (tankmix) at 7 DAS+ Mechanical weeding (Cono weeder) at 30 DAS, T₆.PE Pendimethalin 38.7% CS @ 0.65 kg ha⁻¹ 6 DAS + Mechanical weeding (Cono weeder) at 30 DAS, T₇.Mechanical weeding (Cono weeder) at 15 and 30 DAS, T₈.Hand weeding twice at 15 and 30 DAS, T₉.Control (Unweeded check)

From the pooled analysis, application of PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS +POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ (T₁) recorded higher grain and straw yield of 5702 and 6047 kg ha⁻¹ respectively followed by PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ at 7 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ recorded grain and straw yield of 5531 and 5865 kg ha⁻¹ respectively. Control (Unweeded check) recorded lower grain and straw yield of 4149 and 4614 kg ha⁻¹ respectively. With respect to economic analysis, application of PE Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS +POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ (T₁) recorded higher gross income of Rs. 83218, net income of Rs. 47657 with the BC ratio of 2.33 followed by PE Pretilachlor 50% EC @ 0.5 kg ha⁻¹ + PE Pyrazosulfuron ethyl 10% WP @ 10 g ha⁻¹ at 7 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ recorded gross income of Rs. 80703, net income of Rs. 44970 with the BC ratio of 2.25. Control (Unweeded check) recorded lower gross income of Rs. 60808, net income of Rs. 30254 with the BC ratio of 1.98.

Conclusion

Pre-emergence application of Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS followed by post emergence application of Bispyribac sodium 10% EC @ 25 g ha⁻¹ recorded higher weed control efficiency (WCE) of 92%, grain yield of 5702 kg ha⁻¹, net income of 47657/- and B:C ratio 2.33.This treatment recorded 28% higher yield over unweeded control. Direct (drum) seeding technique method of rice cultivation is associated with many advantages but the problem of heterogeneous weed flora becomes the major constraint for adopting this technique widely in the field by farmers. The above research work has clearly brought out the proper

herbicide combination for the management of weeds in wet seeded rice. Farmers can apply Pyrazosulfuron ethyl 10% WP @ 20 g ha⁻¹ at 3 DAS + POE Bispyribac sodium 10% EC @ 25 g ha⁻¹ at 2 - 3 leaf stage of weed for the weed management in direct seeded rice to generate an eco-friendly economically viable the practice of direct rice seeding under water scarce situation

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