Research Article

WEED DENSITY AND PRODUCTIVITY OF DRY DIRECT SEEDED RICE IN RELATION TO WEED MANAGEMENT PRACTICES AND SEEDBED PREPARATION METHODS

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ABSTRACT

Effective weed management practice is important for successful dry direct seeded rice (DDSR) cultivation. Field experiments were conducted during rainy seasons of 2016 and 2017 to assess the effect of herbicides, or herbicides mixture, and seedbeds preparation methods on weed density and grain yield of DDSR. The experiments were done by using two factors factorial strip plot design with four replications. The treatments consisted of nine weed management practices (weed free; weedy check; spraying Pendimethalin; Bispyribac sodium; Ethoxysulfuron; Pendimethalin followed by Bispyribac sodium; Pendimethalin followed by Ethoxysulfuron; Bispyribac sodium tank mix with Ethoxysulfuron, and Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron) as horizontal factor whereas two seedbed preparation methods (stale, and normal seedbed) were considered as the vertical factor. The data were collected and analyzed using MSTAT-C statistical software. Total density and dry matter of weeds were significantly ($p<0.05$) lower in weed free treatment followed by Pendimethalin spray and Bispyribac sodium tank mix with Ethoxysulfuron spray at all the growth stages of rice in both the years. Similarly, rice grain yield was significantly higher ($p<0.05$) in weed free treatment followed by Pendimethalin spray and Bispyribac sodium tank mix with Ethoxysulfuron spray in both the years. Effect of seedbed preparation methods on weed density and dry matter, yield attributes and yield of rice were non-significant. Therefore, Pendimethalin spray followed by Bispyribac sodium tank mix with Ethoxysulfuron spray seems better option for managing weeds in DDSR.

Key words: Weed dry matter, herbicide, stale seedbed, normal seedbed, tank mixture

INTRODUCTION

Rice is staple food of Nepal and ranks the first in terms of area cultivated (1.46 million ha) and production (5.15 million t) with the productivity of 3.50 t ha^{-1} (CBS, 2018). Conventional puddled transplanted rice (CPTR) is the major system of rice production in Nepal but nowadays due to increasing trend of migration of rural labor to cities, acute shortage of labor for transplanting has shifted the paradigm to Direct Seeded rice (DDSR). Less labor requirements and early harvesting of rice in DDSR facilitates timely planting of subsequent crops. Therefore, farmers in many Asian countries are shifting from manual transplanting to direct seeded rice systems (Chauhan, 2012). However, weeds are the main biological constraints in DSR, and if weeds are not controlled timely, yield losses could exceed 90% (Chauhan & Johnson, 2011).

Many options exists for weed control in DDSR, perhaps the most common being the use of herbicides (Mahajan et al., 2014) which have been found effective for pre-plant, pre-emergence and post-emergence weed control in DSR systems, but use of a single-herbicide rarely furnishes season long weed control, so, herbicides tank mixture can prove superior to sole application as it broadens the spectrum of weed control (Damalas, 2005). Also, extensive use of herbicides causes risk of herbicide resistance and environmental contamination, thus, integrated weed management (IWM) strategies, that combines preventive, cultural and chemical methods, is desirable for effective weed control in DSR (Chauhan et al., 2012). Some cultural weed management approaches are the use of a stale seedbed technique, weed competitive cultivars, use of mulches, brown manuring, and use of high seeding rates, proper sowing time, narrow crop rows and optimum time and depth of flooding (Kaur & Singh, 2017). Stale seedbed reduces weed emergence as well as the soil weed seed bank (Rao et al., 2007). This practice is effective for weeds present in the top layers of soil with low initial dormancy and also helps to reduce the problems of hard to control weeds such as *Cyperus rotundus* L., weedy rice and volunteer rice seedlings (Chauhan, 2012). Therefore, this study was done to evaluate the effect of herbicides, or herbicides mixture and seedbed preparation methods on weed density, weed biomass, yield components and rice grain yield in dry direct seeded rice (DDSR).

MATERIAL AND METHODS

Field experiments were conducted during the rainy season of 2016 and 2017 at Regional Agricultural Research Station, Parwanipur, Bara, Nepal. The soil pH of the experimental plot was slightly acidic (5.6) and soil texture was sandy clay loam. The total annual precipitation during the crop cultivation season during 2016 and

2017 were 937.6 mm and 1235.07 mm, respectively. The maximum temperature ranged from 28.42°C to 34.61°C and 28°C to 34.98°C while minimum temperature ranged from 13.37°C to 27.38°C and 13.78°C to 27.55°C during rice growing season of 2016 and 2017, respectively. The soil was medium in soil organic matter (3.31%), total nitrogen (0.17%), low in available phosphorus (7.19 kg ha^{-1}), and medium in available potassium (221.68 kg ha^{-1}).

The experiments were conducted by using strip-plot design with the provision of four replications for each treatment. The treatment consisted of nine weed management practices (Weed free; Weedy check; Pendimethalin spray; Bispyribac sodium spray; Ethoxysulfuron spray; Pendimethalin followed by Bispyribac sodium spray; Pendimethalin followed by Ethoxysulfuron spray; Bispyribac sodium tank mix with Ethoxysulfuron spray, and Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron spray) in horizontal plots whereas two seedbed preparation methods (stale and normal seedbed) were arranged in the vertical plots. The rice variety Radha-4 was seeded manually continuously in line with a row spacing of 20 cm and a seed rate of 45 kg ha^{-1}. Rice was sown with the fertilizer dose of 100:30:30 N, P_2O_5 and K_2O kg ha^{-1}, respectively. Full amount of Phosphorus and Potassium and 1/3rd N was applied as basal application, and remaining 2/3rd nitrogen were applied at 25 days after seeding (DAS), and 45 DAS in two equal splits.

In both of the seedbed preparation method, field was prepared by one deep ploughing followed by three light ploughings and planking, however, in stale seedbed, the field was irrigated and left for 20 days to allow initial flushes of weeds to germinate and then Glyphosate 47% SL (4 mL $liter^{-1}$ of water) was applied to the germinated weeds before the sowing of crops. Weed density was recorded within each plot with the help of a quadrate (0.5 m × 0.5 m) at two places at 30, 60 and 90 days after sowing (DAS) and expressed as weeds m^{-2}, and in the case of weed dry matter, weed samples collected were oven dried at 70^0 C till constant weight, and expressed as g m^{-2}. The data on weeds were subjected to square root transformation to normalize their distribution. Effective tiller m^{-2} was recorded from net plot area of individual plot. Grains $panicle^{-1}$ was recorded from 20 randomly selected panicles per plot. Thousand grains were taken from the grain yield of each net plot and weighed with the help of portable automatic electronic balance, and expressed in g. Rice grain yield was measured from an area of 4.9 m^2 i.e. net plot area, and expressed in t ha^{-1} at 14% moisture. MSTAT-C software was used for data analysis. All the recorded data were subjected to analysis of variance and Duncan's multiple range test (DMRT) was used for mean comparison. Treatments differences were considered statistically significance at 0.05 levels of significance.

RESULTS AND DISCUSSION

Total weed density and weed dry matter of DDSR

The major weed flora recorded in the experimental site were *Alternanthera philoxiroides* (Mart.) Griseb., *Commelina benghalensis* L., *Cyperus rotundus* L., *Cynodon dactylon* (L.) Pers, *Commelina diffusa* Burm F., *Eclipta alba* (L.) Hassak, *Echinochloa colona* (L.) Link, *Eclipta prostrate* L.*, Eluesine indica* (L.) Gaertn, *Echinochloa crusgali* (L.) P. Beauv., *Euphorbia hirta* L., *Ludwigia hissopifola* (G. Don) Exell, *Lindernia procembens* Phileox., *Murdaniya nudiflora* (L) Brenan, *Portulaca oleraceae* L., and *Spilanthes paniculata* wall ex Dc.

The total density and dry matter of weeds recorded in weedy check were significantly higher ($p<0.05$) in comparison to weed free treatments at all the growth stages of rice (30, 60 and 90 DAS) during the both years 2016 and 2017 (Table 1 & 2). Lowest weed density from weed free treatment, and highest from control plot in direct seeded rice was also reported by Saravanane et al. (2016). Similarly, Rajaput (2013) had recorded higher total weed dry matter from weedy check as compared to the rest of the herbicide spray treatments at all the growth stages of DSR and reported that it was mainly due to the higher and uninterrupted growth of weeds.

On the other hands, all the herbicide applied treatments had a reduced total density and dry matter of weeds as compared to weedy check at all the growth stages of rice during both the years (Table 1). Similar results were also reported by Mahajan & Chauhan (2015). It was equally observed that sequential application of pre- and post-emergence herbicides effectively controlled total density and dry matter of weeds than sole application of either pre or post emergence herbicides. Among the herbicide applied treatments, Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron spray was significantly ($p<0.05$) superior over rest of the treatments in terms of reducing the density and dry matter of weeds at all the growth of stages of rice. The subsequent effective treatments were Pendimethalin followed by Bispyribac sodium spray and Pendimethalin followed by Ethoxysulfuron spray (Table 1 & 2). Kumar & Singh (2016) also reported sequential application of Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron spray effective and was significantly superior over rest of the treatments in minimizing weed density at different growth stages of direct seeded rice. Similarly, Kumar & Singh (2016) reported

application of Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron spray as significantly superior over rest of the treatments in minimizing weed dry matter at different stages of observation in direct seeded rice. Likewise, superiority of tank mixtures of herbicides in order to reduce weeds population as compared to sole application of herbicide was also reported by Mahajan & Chauhan (2015) and had further suggested that tank mixing of herbicides might have greater synergistic effect for broad spectrum control of weeds. Effect of seedbed preparation methods on total weed density and dry matter was, however, non significant ($p>0.05$) at all the growth stages of rice during both the years (Table 1 & 2).

Table 1. Total weed density (number m^{-2}) as influenced by weed management practices and seedbed preparation methods at RARS, Parwanipur, Bara, Nepal during 2016 and 2017

Treatments	Total weed density (Number m^{-2})					
	30 DAS		60 DAS		90 DAS	
	2016	2017	2016	2017	2016	2017
Weed management practices						
Weed free	6.90^{h} (50.00)	5.04^{h} (25.75)	4.46^{g} (20.50)	2.91^{g} (8.12)	3.06^{g} (9.50)	2.57^{h} (6.50)
Weedy check	22.53^{a} (509.80)	16.35^{a} (268.30)	17.53^{a} (307.80)	14.55^{a} (212.00)	14.81^{a} (219.80)	12.82^{a} (164.10)
Pendimethalin	14.75^{b} (219.90)	12.76^{b} (162.90)	12.67^{b} (164.60)	10.64^{b} (114.10)	10.97^{b} (123.10)	9.30^{b} (87.13)
Bispyribac Na	11.97^{cd} (144.40)	9.90^{d} (98.63)	9.41^{cd} (89.13)	8.27^{c} (69.00)	7.33^{d} (54.88)	6.72^{d} (45.63)
Ethoxysulfuron	12.68^{c} (162.10)	10.45^{c} (110.00)	10.29^{c} (105.80)	8.81^{c} (77.75)	8.72^{c} (77.00)	7.50^{c} (56.13)
Pendimethalin *fb* Bispyribac Na	9.894^{f} (101.00)	8.07^{f} (66.00)	7.71^{e} (60.25)	6.28^{e} (39.25)	5.64^{ef} (33.00)	5.25^{f} (27.63)
Pendimethalin *fb* Ethoxysulfuron	10.28^{ef} (106.60)	8.51^{ef} (73.00)	8.74^{d} (78.00)	6.79^{de} (46.00)	6.04^{e} (41.13)	5.87^{e} (34.25)
Bispyribac Na tank mix with Ethoxysulfuron	11.21^{de} (125.60)	8.95^{e} (80.50)	9.30^{cd} (86.88)	7.18^{d} (52.00)	7.26^{d} (55.13)	6.44^{d} (41.38)
Pendimethalin *fb* Bispyribac Na tank mix with Ethoxysulfuron	8.77^{g} (79.38)	7.10^{g} (52.00)	6.62^{f} (46.25)	5.37^{f} (28.63)	5.12^{f} (27.38)	4.01^{g} (16.00)
LSD (P=0.05)	1.06	0.49	0.99	0.61	0.77	0.49
SEm ±	0.36	0.16	0.34	0.21	0.26	0.16
Seedbed preparation methods						
Stale seedbed	11.98^{a} (167.40)	9.63^{a} (103.80)	9.48^{a} (104.30)	7.83^{a} (71.92)	7.49^{a} (70.58)	6.66^{a} (53.08)
Normal seedbed	1.24 ^{a}(165.6 0)	9.72^{a} (104.40)	9.79^{a} (108.90)	7.90^{a} (71.83)	7.83^{a} (71.83)	6.78^{a} (53.31)
LSD (P=0.05)	1.44	2.31	2.58	0.80	3.44	0.40 10.09
SEm ±	0.32	0.51	0.57	0.17	0.76	11.33
CV %	13.09	11.00	11.73	10.97	20.54	
Grand mean	12.11	9.68	9.64	7.87	7.66	6.72

Note: Data subjected to square-root (√X+0.5) transformation; figures in parentheses are original values; Means followed by the common letter (s) within a column are non-significantly different based on DMRT at p = 0.05

Table 2. Total weed dry matter (g m^{-2}) as influenced by weed management practices and seedbed preparation methods at RARS, Parwanipur, Bara, Nepal during 2016 and 2017

Treatments	Total weed dry matter (g m^{-2})					
	30 DAS		60 DAS		90 DAS	
	2016	2017	2016	2017	2016	2017
Weed management practices						
Weed free	3.66^{g} (13.17)	3.86^{g} (14.72)	2.99^{h} (8.73)	3.18^{g} (9.77)	3.55^{f} (12.98)	2.34^{g} (5.01)
Weedy check	16.35^{a} (268.90)	14.15^{a} (200.90)	14.47^{a} (210.10)	13.02^{a} (172.60)	12.43^{a} (155.20)	11.01^{a} (121.20)
Pendimethalin	11.67^{b} (136.20)	10.49^{b} (110.70)	9.79^{b} (96.49)	9.38^{b} (88.88)	8.41^{b} (70.97)	7.42^{b} (56.39)
Bispyribac Na	9.23^{d} (85.24)	8.80^{c} (78.33)	7.68^{d} (58.93)	6.94^{cd} (48.17)	7.11^{c} (50.52)	5.63^{cd} (32.81)
Ethoxysulfuron	9.95^{c} (99.46)	9.14^{c} (84.50)	8.31^{c} (69.23)	7.24^{c} (52.41)	7.10^{c} (50.52)	6.11^{c} (37.27)
Pendimethalin *fb* Bispyribac Na	7.21^{e} (52.09)	6.73^{e} (45.66)	5.77^{f} (33.01)	5.76^{e} (33.30)	5.74^{d}(32.89)	4.74^{e} (22.51)
Pendimethalin *fb* Ethoxysulfuron	7.02^{e} (49.43)	7.14^{de} (51.27)	6.17^{f} (38.12)	6.27^{de} (39.29)	5.97^{d} (35.58)	5.33^{de} (28.15)
Bispyribac Na tank mix with Ethoxysulfuron	6.98^{e} (48.56)	7.35^{d} (54.27)	6.62^{e} (43.60)	6.63^{cd} (43.71)	6.73^{c} (45.26)	5.78^{cd} (33.26)
Pendimethalin *fb* Bispyribac Na tank mix with Ethoxysulfuron	5.63^{f} (31.54)	5.74^{f} (33.10)	5.10^{g} (25.85)	4.81^{f} (23.08)	4.98^{e} (24.45)	3.42^{f} (11.77)
LSD (P=0.05)	0.52	0.53	0.44	0.66	0.50	0.60
SEm ±	0.17	0.18	0.15	0.22	0.17	0.20
Seedbed preparation methods						
Stale seedbed	8.65^{a} (88.80)	8.09^{a} (74.36)	0.24^{a} (65.35)	7.00^{a} (56.99)	6.89^{a} (53.96)	5.77^{a} (39.45)
Normal seedbed	8.62^{a} (85.55)	8.22^{a} (75.28)	7.49^{a} (64.44)	7.05^{a} (56.61)	6.90^{a} (52.34)	5.73^{a} (37.96)
LSD (P=0.05)	1.11	1.40	1.59	0.77	1.22	0.56
SEm ±	0.24	0.31	0.35	0.17	0.27	0.12
CV %	10.16	9.68	9.02	14.18	10.70	16.01
Grand mean	8.63	8.16	7.43	7.02	6.89	5.75

Note: Data subjected to square-root (√X+0.5) transformation; figures in parentheses are original values; Means followed by the common letter (s) within a column are non-significantly different based on DMRT at p= 0.05

Yield attributes of DDSR

Highest number of effective tiller m^{-2} and grains $panicle^{-1}$ were recorded for weed free treatment while weedy check had recorded the lowest numbers of weed (Table 3). Highest numbers of panicles m^{-2} in less weed-competitive environment i.e. weed free treatment as compared to high weed-competitive environment i.e. weedy check was also reported by Chuahan et al. (2015) and thought that it was perhaps due to greater space occupied by the rice plants and their low competition with weeds for water, nutrient and light in less weed-competitive environment. All the weed management treatments recorded significantly higher number of grains $panicle^{-1}$ over weedy check (Table 3) which was due to lower density and dry matter of weeds and higher weed control efficiency (Singh et al., 2013; Raghavendra et al., 2015).

Among the herbicide applied treatments, Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron spray, and Pendimethalin followed by Bispyribac sodium spray had statistically similar ($p>0.05$), but higher number of effective tiller m^{-2} and grains $panicle^{-1}$ in both years ($p<0.05$) (Table 3). Kumar et al. (2018) also reported higher numbers of effective tiller m^{-2} from Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron spray as compared to weedy check. Increased number of rice tillers per m^2 area in all the herbicide sprayed treatments as compared to weedy check treatment was also reported by several researchers (Pinjari et al., 2016; Shahbaz et al., 2018). Similarly, Kumar et al. (2018) also had reported significantly higher ($p<0.05$) number of grains $panicle^{-1}$ from weed free treatment which was statistically similar ($p>0.05$) with the treatment-Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron spray in comparison to weedy check.

Effect of weed management practices on thousand grain weight was non significant ($p>0.05$) during 2016 while in 2017, all the other treatments had statistically similar ($p>0.05$), but had higher values ($p<0.05$) for thousand grain weight, except for the treatment with weedy check, and pendimethalin applied plots (Table 3). Kumar et al. (2018) also reported significantly higher values of thousand grain weight from Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron spray which was statistically similar ($p>0.05$) with weed free treatment. Significantly higher values of sterility percentage were recorded for weedy check while lower values were recorded for weed free treatment (Table 3). Among the herbicide applied treatments, Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron spray had recorded significantly lower ($p<0.05$) values of sterility percentage during both the years but was statistically similar ($p>0.05$) with Pendimethalin followed by Bispyribac sodium spray and Pendimethalin followed by Ethoxysulfuron spray during the year of 2016 (Table 3) while it was statistically similar ($p>0.055$) with Pendimethalin followed by Bispyribac sodium spray and Pendimethalin followed by Ethoxysulfuron spray as well as the treatment with Bispyribac sodium tank mix with Ethoxysulfuron spray during the period of in 2017 (Table 3). The effects of seedbed preparation on all the yield attributing characters of DDSR were, however, statistically non-significant ($p>0.05$) (Table 3).

Table 3. Yield attributes of rice as influenced by weed management practices and seedbed preparation methods at RARS, Parwanipur, Bara, Nepal during 2016 and 2017

Treatments	Effective tiller m^{-2}		Grains $panicle^{-1}$		1000-grain weight (g)		Sterility %	
	2016	2017	2016	2017	2016	2017	2016	2017
Weed management practices								
Weed free	266.50^{a}	317.40^{a}	140.80^{a}	168.30^{a}	22.80	22.87^{ab}	9.42^{d}	7.384^{e}
Weedy check	122.60^{f}	127.40^{f}	74.50^{f}	109.20^{f}	22.57	22.34^{c}	14.27^{a}	12.68^{a}
Pendimethalin	152.10^{e}	188.90^{e}	108.20^{e}	123.80^{e}	22.80	22.67^{b}	12.31^{b}	10.71^{b}
Bispyribac Na	174.60^{d}	221.60^{d}	123.10^{d}	133.50^{de}	22.82	22.86^{ab}	11.37^{bc}	10.03^{bc}
Ethoxysulfuron	158.30^{e}	221.40^{d}	121.80^{d}	141.40^{cd}	22.79	22.85^{ab}	12.48^{b}	9.31^{cd}
Pendimethalin *fb* Bispyribac Na	198.80^{c}	267.90^{bc}	130.40^{bc}	158.70^{ab}	22.81	22.95^{ab}	10.84^{bcd}	8.09^{e}
Pendimethalin *fb* Ethoxysulfuron	194.80^{c}	250.30^{c}	125.40^{cd}	154.90^{b}	22.80	22.81^{ab}	9.74^{cd}	8.19^{de}
Bispyribac Na tank mix with Ethoxysulfuron	177.50^{d}	251.50^{c}	119.10^{d}	152.40^{bc}	22.83	22.93^{ab}	12.24^{b}	8.43^{de}
Pendimethalin *fb* Bispyribac Na tank mix with Ethoxysulfuron	225.40^{b}	284.00^{b}	134.00^{b}	161.80^{ab}	22.84	23.01^{a}	9.64^{cd}	7.65^{e}
LSD (P=0.05)	14.74	26.45	6.54	11.22	ns	0.25	1.66	1.10
SEm ±	5.05	9.06	2.24	3.84	0.08	0.08	0.57	0.37
Seedbed preparation methods								
Stale seedbed	185.90^{a}	238.10^{a}	119.80^{a}	145.30^{a}	22.78^{a}	22.83^{a}	11.42^{a}	9.17^{a}
Normal seedbed	185.30^{a}	235.30^{a}	119.60^{a}	144.50^{a}	22.79^{a}	22.79^{a}	11.32^{a}	9.16^{a}
LSD (P=0.05)	29.08	80.51	8.76	14.17	0.57	0.37	4.20	5.07
SEm ±	6.46	17.89	1.94	3.14	0.12	0.08	0.93	1.12
CV %	12.33	16.90	7.35	9.49	1.66	2.06	17.72	17.36
Grand mean	185.61	236.69	119.72	144.90	22.78	22.81	11.37	9.16

Note: Data subjected to square-root (√X+0.5) transformation; figures in parentheses are original values; Means followed by the common letter (s) within a column are non-significantly different based on DMRT at p = 0.05

Grain yield, straw yield and harvest index

All the weed management treatments produced significantly higher grain yield ($p<0.05$) over weedy check (Table 4). Dhanapal et al. (2018) also observed similar results and reported that it was due to reduced density and biomass of weeds at all the growth stages of crop, which increased dry matter of rice and number of panicles m^{-2}. Significantly higher grain yield was recorded in weed free treatment in our experiments (Table 4) which was followed by the treatment with Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron spray during both the years (Table 4). Among the herbicides applied treatments, the higher rice grain yield was recorded from treatments with pre-emergence followed by post-emergence herbicides as compared to sole application of herbicides which was mainly due to the visible contribution of higher yield attributing parameters recorded in these treatments. Similar results were also reported by Vivek et al. (2018). Similarly, Kumar et al. (2018) reported significantly higher values of grain yield of direct seeded rice from Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron spray as compared to rest of the treatments which was also similar as that of weed free situation whereas weedy plots produced the lowest grain yield (Table 4).

The effect of seedbed preparation methods (stale seedbed and normal seedbed) on grain yield was statistically non-significant ($p>0.05$) during both the years. The results recorded in out experiments was, however, in contrast to the findings of Rao et al. (2007), where stale seedbed significantly decreased the density and dry matter of weeds which increased the grain yield than in normal seedbed. On the other hand, Marhatta et al. (2017) reported non-significant ($p>0.05$) effect of seedbed preparation methods (stale and normal seedbed) on grain yield of DDSR. The authors had explained the reasons of such results in relation to the land preparation time and condition of precipitation (there was rainfall for few days after application of irrigation to the stale seedbed which caused germination of some weed seeds in the normal seedbed as well). They also reported that the soil in the stale seedbed become compacted due to the application of irrigation which required slight intensive tillage compared to normal seedbed which caused more weed seeds in lower depth were exposed and germinated in the stale seedbed.

Significantly higher ($p<0.05$) rice straw yield was recorded in weed free treatment in both the years but it was statistically similar ($p>0.05$) to the treatments with Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron spray; Pendimethalin followed by Bispyribac sodium spray, and Pendimethalin followed by Ethoxysulfuron spray during the period of 2016 experiment whereas it was statistically similar ($p>0.05$) with the treatments Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron spray and Pendimethalin followed by Bispyribac sodium spray during the year of 2017 experiment (Table 4). Higher straw yield in these treatments was due to more dry matter production per unit area caused by better nutrient absorption from soil, increased rate of metabolic processes, rate of light absorption, photosynthetic activity and more number of leaves (Kumar et al., 2018). Significantly higher values of straw yield with Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron spray treatment which was statistically similar ($p>0.05$) with weed free situation whereas least straw yield from weedy check plot was also reported by Kumar et al. (2018) and the authors had reported least straw yield in weedy treatments mainly due to presence of higher weed biomass in the treatments which affected the vegetative and reproductive phases of rice crop adversely (Table 4).

Harvest index was significantly higher ($p<0.05$) in weed free treatments whereas lowest index was calculated in weedy check treatment (Table 4). Lower harvest index under weedy check condition may be due to the menace of weeds go increasing with increase in age and hence, the vegetative growth was affected comparatively less than the reproductive growth of rice plants lowering the harvest index (Kumar et al., 2018). Lowest harvest index in weedy check plot was also reported by Choudhary & Dixit (2018). Among the herbicide applied treatments, Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron spray had significantly higher values of harvest index during both years which was also statistically similar ($p>0.05$) with Pendimethalin followed by Bispyribac sodium spray as revealed in the year 2016. However, the effect of seedbed preparation methods on grain yield, straw yield and harvest index were statistically non-significant ($p>0.05$) during both the years (Table 4).

Table 4. Grain yield of rice, straw yield, and harvest index as influenced by weed management practices and seedbed preparation methods at RARS, Parwanipur, Bara, Nepal during 2016 and 2017

Treatments	Grain Yield (t ha^{-1})		Straw Yield (t ha^{-1})		Harvest Index (%)	
	2016	2017	2016	2017	2016	2017
Weed management practices						
Weed free	4.29^{a}	4.68^{a}	5.95^{a}	6.66^{a}	40.28^{a}	42.32^{a}
Weedy check	1.72^{g}	1.66^{g}	3.85^{e}	2.60^{e}	30.98^{e}	36.30^{f}
Pendimethalin	2.58^{f}	2.40^{f}	4.41^{d}	4.30^{d}	38.53^{bc}	37.61^{e}
Bispyribac Na	2.98^{e}	3.25^{e}	5.98^{a}	5.87^{bc}	36.91^{cd}	38.81^{d}
Ethoxysulfuron	3.04^{e}	3.20^{e}	5.40^{c}	5.66^{c}	36.73^{d}	38.76^{d}
Pendimethalin *fb* Bispyribac Na	3.69^{c}	4.05^{c}	5.79^{ab}	6.31^{ab}	38.76^{ab}	40.90^{bc}
Pendimethalin *fb* Ethoxysulfuron	3.58^{c}	3.84^{cd}	5.89^{a}	5.95^{bc}	37.94^{bcd}	40.49^{c}
Bispyribac Na tank mix with Ethoxysulfuron	3.34^{d}	3.68^{d}	5.52^{bc}	5.93^{bc}	38.02^{bcd}	40.29^{c}
Pendimethalin *fb* Bispyribac Na tank mix with Ethoxysulfuron	3.98^{b}	4.38^{b}	5.83^{ab}	6.66^{a}	39.17^{ab}	41.49^{ab}
LSD (P=0.05)	0.15	0.29	0.32	0.46	1.51	0.90
SEm ±	0.05	0.09	0.11	0.15	0.52	0.30
Seedbed preparation methods						
Stale seedbed	3.24^{a}	3.47^{a}	5.45^{a}	5.53^{a}	37.52^{a}	39.76^{a}
Normal seedbed	3.25^{a}	3.45^{a}	5.36^{a}	5.57^{a}	37.44^{a}	39.57^{a}
LSD (P=0.05)	0.99	0.54	0.61	0.57	3.00	2.65
SEm ±	0.22	0.12	0.13	0.12	0.58	0.66
CV %	8.14	10.65	15.65	11.27	5.16	3.52
Grand mean	3.24	3.46	5.40	5.55	37.48	39.66

Note: Data subjected to square-root (√X+0.5) transformation; figures in parantheses are original values; Means followed by the common letter (s) within a column are non-significantly different based on DMRT at p = 0.05.

CONCLUSION

Pendimethalin followed by Bispyribac sodium tank mix with Ethoxysulfuron spray proved much effective against diverse weed flora for producing higher grain yield, other than weed free check treatment in DDSR. Effect of seedbed preparation methods on weeds, yield and yield attributes of rice were, however, non-significant. This result thus confirms the effective use of Pendimethalin spray followed by Bispyribac sodium tank mix with Ethoxysulfuron spray in order to manage DDSR technique against weed infestation.

ACKNOWLEDGEMENTS

The authors are grateful to the Nepal Agricultural Research Council for support in field research activities and Regional Agricultural Research Station, Parwanipur, Bara, Nepal for providing facilities for conducting research.

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