Effect of seedbed preparation methods and herbicide application on yield and economics of dry direct-seeded rice at Parwanipur, Nepal

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Abstract
Field experiments were conducted during the 2016 and 2017 normal season (June-November) dry direct-seeded rice (DDSR) at RARS Parwanipur to assess the effect of various combinations of herbicides mixture under seedbed preparation to evaluate different attributes of weed control efficiencies (WCE) coupled with grain yield and economics of DDSR. The experiment was laid out in two factors factorial strip plot design with four replications. Treatments consisted of nine levels of weed management practices that include weed free, weedy check, Pendimethalin, Bispyribac sodium, Ethoxysulfuron, Pendimethalin followed by (*fb*) Bispyribac sodium, Pendimethalin *fb* Ethoxysulfuron, Bispyribac sodium tank mix with Ethoxysulfuron and Pendimethalin *fb* tank mixture of Bispyribac sodium and Ethoxysulfuron as horizontal factor whereas two levels of seedbed preparation methods (stale seedbed and normal seedbed) as the vertical factor. The result of the experiments revealed lower weed intensity (WI) and higher weed control efficiency (WCE), net return and benefit-cost (B:C) ratio with Pendimethalin *fb* tank mixture of Bispyribac sodium and Ethoxysulfuron in both the years 2016 and 2017. Grain yield was significantly higher with weed free treatment followed by Pendimethalin *fb* tank mixture of Bispyribac sodium and Ethoxysulfuron in both the years due to higher WCE and lower WI which resulted in better growth and development of DDSR. Therefore, the Pendimethalin *fb* tank mixture of Bispyribac sodium and Ethoxysulfuron is a better option for DDSR under Parwanipur condition during main season rice DDSR rice production.

Keywords: direct-seeded rice, herbicide, tank mixture, weed control efficiency, weed index

Introduction
Puddled transplanted rice (PTR) is the major system of rice production in Nepal. These days due to the scarcity of manual labor weed control has become a menace to rice growers. In direct seeded rice (DSR), there are fewer labor requirements and can also be harvested earlier than PTR systems which facilitate the timely planting of subsequent crops. However, weeds are the main biological constraints in DSR (Chauhan and Johnson, 2010) and can cause yield loss of more than 90% if weeds are not controlled timely (Chauhan and Johnson, 2011). Herbicides are the most common for weed control in DSR (Mahajan *et al.*, 2014). However, the use of a single-herbicide can't control all weed species; so, herbicides tank mixture proved to be superior as it broadens the spectrum of weed control (Damalas, 2005). But, extensive use of herbicides causes the risk of herbicide resistance, so, integrated weed management strategies, that includes preventive, cultural and chemical methods is desirable for effective weed control in DSR (Chauhan *et al.*, 2012). In cultural weed management, a stale seedbed system reduces weed emergence as well as the soil weed seed bank (Rao *et al.*, 2007). Therefore, this experiment was conducted to evaluate the effect of herbicides/ herbicides mixture and seedbed preparation methods in weed management in dry direct-seeded rice.

Materials and methods
Field experiments were conducted at the Regional Agricultural Research Station (RARS), Parwanipur, Bara, Nepal during the rainy season (June to November) of 2016 to 2017. The geographical location of the site was at an altitude of 120 m above mean sea level, 27°20' N (latitude) and 84°53' E (longitude). The experiment was conducted in a strip-plot design with four replications. The treatment consisted of nine levels of weed management practices (Weed free, Weedy check, Pendimethalin @ 1000 g a.i. /ha,

Bispyribac sodium @ 25 g a.i. /ha, Ethoxysulfuron @ 18 g a.i. /ha, Pendimethalin @ 1000 g a.i. /ha *fb* Bispyribac sodium @ 25 g a.i. /ha, Pendimethalin @ 1000 g a.i. /ha *fb* Ethoxysulfuron @ 18 g a.i. /ha, Bispyribac sodium @ 25 g a.i. /ha tank mix with Ethoxysulfuron @ 18 g a.i. /ha and Pendimethalin @ 1000 g a.i. /ha *fb* tank mixture of Bispyribac sodium @ 25 g a.i. /ha and Ethoxysulfuron @ 18 g a.i. /ha) in horizontal plots whereas two levels of seedbed preparation methods (stale seedbed and normal seedbed) in the vertical plots. The size of the individual plot was 13.5 m^2 (4.5 m x 3 m). The rice variety Radha-4 was seeded manually continuously in line with a row spacing of 20 cm with a seed rate of 45 kg/ha. Rice was sown with the fertilizer dose of 100:30:30 N, P_2O_5 and K_2O kg /ha, respectively. The full amount of Phosphorus and Potassium and 1/3rd N was applied as basal application and the remaining 2/3rd of nitrogen were applied at 25 days after seeding (DAS) and 45 DAS in two equal splits. Zinc sulphate @ 25 kg /ha was also applied at final land preparation.

Normal seedbed was maintained by one deep ploughing followed by three light ploughings and planking while stale seedbed was maintained by one deep ploughing followed by three light ploughings and planking and field was irrigated and left for 20 days to allow to germinate initial flushes of weeds and then Glyphosate 47% SL (4 ml /litre of water) was applied to the appeared weeds before the sowing of crops. For weed control efficiency, observation regarding the weed density was recorded within each plot with the help of a quadrate (0.5 m x 0.5 m) at two places at 30, 60 and 90 DAS and in the case of weed index, grain yield from weed free plot and treatment plot for which weed index to be worked out was recorded. For the leaf area index, plants were taken from a 25 cm row length of the destructive sampling row. Number of tiller /m^2 was counted from marked one meter of the row of each plot. For dry matter accumulation, plant samples were taken from 25 cm row length of destructive sampling row and expressed in g /m^2. Grain yield was measured from an area of 4.9 m^2 from the net plot area and expressed in t /ha 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) for mean separations. Treatments differences were considered statistically significance at 0.05 levels of significance.

Results and Discussions

The maximum temperature ranged from 30.02°C to 34.00°C and 29.32°C to 33.71°C during the rice growing season in 2016 and 2017, respectively. The minimum temperature ranged from 14.46°C to 26.80°C and 15.36°C to 26.73°C during the rice-growing season of 2016 and 2017, respectively. The total annual rainfall during the crop season of 2016 and 2017 was 937.6 mm and 1235.07 mm, respectively. The soil texture of the experimental plot was sandy clay loam. The soil pH was slightly acidic (5.6 and 5.5), medium in soil organic matter (3.31 and 3.32 %) and total nitrogen (0.17 and 0.18 %), low in available phosphorus (7.19 and 7.28 kg/ha) and medium in available potassium (221.68 and 219.76 kg/ha) during 2016 and 2017, respectively.

Weed control efficiency and weed index

Among the weed management methods, significantly higher WCE was obtained in weed free while lower WCE in weedy check treatment in both the years 2016 and 2017 (Table 3). Higher WCE was due to weed free by hand weeding while lower WCE was due to higher weed infestation during the crop season. Similar results were also reported by (Saravanane *et al.,* 2016). Ranjit and Suwanketnikom (2003) also reported hand weeding as the most effective method of weed control in direct-seeded rice. Further, concerning the herbicide treatments, at 30 and 60 DAS, maximum WCE was recorded under Pendimethalin *fb* tank mixture of Bispyribac sodium and Ethoxysulfuron which was statistically similar with Pendimethalin *fb* Bispyribac sodium in both the years. At 90 DAS, significantly highest WCE was recorded by Pendimethalin *fb* tank mixture of Bispyribac sodium and Ethoxysulfuron in both the years which was statistically similar with Pendimethalin *fb* Bispyribac sodium in 2016. In these treatments, the involvement of pre-emergence herbicide (Pendimethalin) recorded a significantly higher role in effectively controlling weeds in dry direct seeded rice. Similar results were also reported by Bhurer *et al.*,

(2013a). Higher WCE under these treatments were due to the higher efficiency of these herbicides to control weeds (Gaurav *et al.*, 2015).

Significantly, higher WI was observed in weedy check treatment while lower in Pendimethalin *fb* tank mixture of Bispyribac sodium and Ethoxysulfuron in both the years. Higher weed index was due to severe crop-weed competition for nutrients, soil moisture and light resulting in reduced growth attributes and grain yield of directed seeded rice. Similar results were also observed by (Rajaput, 2013). The lower values of WI was due to the efficient control of weeds by pre-emergence herbicide followed by tank mixtures of post-emergence of herbicides which improved growth of crops and reduction in the crop weed competition. Hence, higher yield. The lowest weed index in tank mixture of herbicide was also reported by (Khaliq *et al*., 2012a). The effect of seedbed preparation methods on WCE and WI was not significant in both years.

Table 1. Weed control efficiency (%) and weed index (%) as influenced by weed management practices and seedbed preparation methods of DDSR during 2016-2017, Parwanipur, Bara, Nepal

Treatments	Weed control efficiency (WCE) %						Weed index (WI) %	
	30 DAS		60 DAS		90 DAS			
	2016	2017	2016	2017	2016	2017	2016	2017
Weed management practices								
Weed free	89.57^{a}	90.01^{a}	95.88^{a}	95.88^{a}	95.21^{a}	95.93^{a}	-	-
Weedy check	-	-	-	-	-	-	59.79^{a}	65.06^{a}
Pendimethalin (Pend)	53.28^{f}	36.65^{e}	41.77^{f}	41.77^{e}	38.76^{f}	45.62^{g}	40.00^{b}	49.50^{b}
Sodium Bispyribac (Bispy	69.39^{de}	61.90^{cd}	70.56^{de}	66.01^{d}	72.40^{d}	71.49^{e}	30.83^{c}	31.60^{c}
Ethoxysulfuron (Ethoxy)	65.63^{e}	57.87^{d}	64.62^{e}	60.33^{d}	61.73^{e}	64.57^{f}	29.32^{c}	32.60^{c}
Pendimethalin *fb* Bispy	78.47^{bc}	74.79^{abc}	79.80^{bc}	80.10^{bc}	83.61^{bc}	82.56^{c}	14.04^{e}	14.96^{e}
Pendimethalin *fb* Ethoxy	77.38^{c}	71.61^{bcd}	73.89^{cd}	76.76^{c}	79.72^{c}	78.48^{cd}	16.72^{e}	19.26^{de}
Bispy tank mix with Ethoxy	73.50^{cd}	68.51^{bcd}	71.12^{de}	73.99^{c}	72.51^{d}	74.03^{de}	22.19^{d}	22.53^{d}
Pend *fb*tank mix of Bispy and Ethoxy	83.08^{b}	80.28^{ab}	84.30^{b}	85.59^{b}	86.53^{b}	89.89^{b}	7.41^{f}	7.94^{f}
LSD (P<0.05)	5.06	14.82	6.92	6.81	5.50	4.71	3.68	6.24
Seedbed preparation methods								
Stale seedbed	66.16	59.65	65.64	63.76	66.70	66.72	24.72	26.95
Normal seedbed	65.02	59.86	63.68	63.79	64.52	66.57	24.33	27.16
LSD (P<0.05)	ns	ns	ns	ns	ns	ns	ns	ns
CV %	10.96	11.76	14.89	10.90	18.91	8.95	26.47	27.18
Grand mean	65.58	60.18	64.65	64.49	65.61	66.95	24.47	27.05

Note: *fb-followed by, means followed by the common letter/s within a column are not significantly different based on DMRT at P <0.05*

Growth attributes and grain yield

The LAI, tiller/m^2, dry matter accumulation and grain yield differed significantly due to weed management practices (Table 4). Weed free recorded significantly highest LAI during both the years which was statistically at par with Pendimethalin *fb* tank mixture of Bispyribac sodium and Ethoxysulfuron and Pendimethalin *fb* Bispyribac sodium in 2016 and Pendimethalin *fb* tank mixture of

Bispyribac sodium and Ethoxysulfuron, Pendimethalin *fb* Bispyribac sodium, Pendimethalin *fb* Ethoxysulfuron and Bispyribac sodium tank mix with Ethoxysulfuron in 2017. Higher LAI in these treatments was due to the effective control of weeds and lower crop-weed competition throughout the crop growth period. Higher values of LAI in weed free treatment in direct seeded rice was also reported by Singh *et al.,* (2017). Similarly, Khaliq *et al.,* (2012b) reported the highest LAI of direct seeded rice from weed free treatment and tank mixtures of Bispyribac sodium and Ethoxysulfuron. Higher LAI in weed free and Pendimethalin *fb* tank mixture of Bispyribac sodium and Ethoxysulfuron was also observed by Marasini (2018). Significantly lower number of tiller /m^2 was recorded in weedy check while a significantly higher number of tiller /m^2 was recorded with weed free treatment which was superior over rest of the treatments and it was followed by Pendimethalin *fb* tank mix of Bispyribac sodium and Ethoxysulfuron and Pendimethalin *fb* Bispyribac sodium in both the years of experiment. A higher number of tiller/m^2 in these treatments was due to higher weed control efficiency which resulted in crop absorbing the required amount of nutrient, water and sunlight for their growth and tillering behaviour. Weed free recorded significantly higher dry matter accumulation which was followed by Pendimethalin *fb* tank mixture of Bispyribac sodium and Ethoxysulfuron in both the years of experimentation. Higher dry matter accumulation in such treatments was due to higher leaf area index. Khaliq *et al.,* (2012b) reported higher LAI led to more interception of radiation over a longer time.

A minimum grain yield was recorded in weedy check while a maximum grain yield recorded in weed free condition in both years (Table 4). The grain yield in 2017 was higher than in 2016 due to favorable total rainfall which was well distributed during the crop growth stages of rice resulting in better crop growth and development. Higher grain yield in weed free treatment was also reported by Bhurer *et al.,* (2013b). All the herbicide treatments produced significantly higher grain yield over the weedy check. Similar results were also observed by Sharma *et al.,* (2016) and reported it was due to the reduced crop weed competition. Among the herbicide treatments, significantly higher grain yield was recorded in the Pendimethalin *fb* tank mixture of Bispyribac sodium and Ethoxysulfuron. Thus, the higher grain yield was observed with the involvement of pre-emergence herbicide i.e. Pendimethalin followed by post-emergence herbicides as compared to sole application of herbicides either pre-or post-emergence herbicides which were due to increased growth attributes, higher weed control efficiency and lower weed index recorded in these treatments. The involvement of Pendimethalin as an effective pre-emergence herbicide for weed control in direct-seeded rice was also reported by Bhurer *et al.,* (2013b). Significantly higher grain yield of direct-seeded rice from Pendimethalin *fb* tank mixture of Bispyribac sodium and Ethoxysulfuron was also reported by Kumar *et al.,* (2018) which was similar to that of weed free situation. Similarly, higher grain yield from Pendimethalin followed by a tank mixture of post-emergence herbicides was also reported by (AGD, 2013).

Effect of seedbed preparation methods (stale seedbed and normal seedbed) on growth attributes and yield were not significant in both the years (Table 4). The reason for the not significant effect could be due to land preparation done at the same time in both seedbed systems but there was rainfall few days after application of irrigation in stale seedbed which resulted in germination of some weeds in normal seedbed also. Similarly, due to the application of irrigation, the soil became compact in stale seedbed which required slight intensive tillage for seeding of rice and caused exposed of more weed seeds from the lower depth of soil and germinated in the stale seedbed. Similar findings were also reported by Marhatta *et al.*, (2017).

Economics of DDSR

The highest total cost of cultivation was found in weed free treatment followed by Pendimethalin *fb* tank mixture of Bispyribac Na and Ethoxysulfuron while the lowest value was incurred in weedy check treatment in both the years (Table 2). The higher cost of cultivation in weed free plot was attributed to the higher labor cost required for intensive weeding while the lower cost of cultivation was observed with weedy check plot due to not additional cost incurred for managing weeds. Significantly, the higher gross

return was recorded with weed free and lowest for weedy check treatment (Table 2). A similar observation was also reported by Kashid *et al.*, (2015). However, weed free condition recorded highest gross return having a high cost which indicated that the treatment was uneconomical (Chakraborti *et al.*, 2017). Among the herbicide applied treatments, a significantly higher gross return was observed with Pendimethalin *fb* tank mixture of Bispyribac sodium and Ethoxysulfuron.

Table 2. Growth attributes and yield as influenced by weed management practices and seedbed preparation methods of DDSR during 2016-2017, Parwanipur, Bara, Nepal

Treatment	LAI		Tiller /m^2		DM accumulation (g /m^2)		Grain yield (t/ha)	
	60 DAS		60 DAS		60 DAS			
	2016	2017	2016	2017	2016	2017	2016	2017
Weed management practices								
Weed free	2.35^{a}	2.38^{a}	556.80^{a}	646.60^{a}	318.70^{a}	329.40^{a}	4.29^{a}	4.68^{a}
Weedy check	1.55^{e}	1.66^{e}	246.90^{f}	375.60^{f}	148.50^{e}	156.90^{f}	1.72^{g}	1.66^{g}
Pendimethalin (Pend)	1.84^{d}	1.90^{d}	419.00^{e}	518.90^{e}	217.20^{d}	221.10^{e}	2.58^{f}	2.40^{f}
Sodium Bispyribac (Bispy)	1.91^{d}	2.01^{cd}	422.60^{e}	547.60^{de}	226.30^{d}	235.10^{e}	2.98^{e}	3.25^{e}
Ethoxysulfuron (Ethoxy)	2.11^{c}	2.08^{bcd}	434.60^{de}	548.90^{de}	248.30^{c}	252.70^{d}	3.04^{e}	3.20^{e}
Pendimethalin *fb* Bispy	2.18^{abc}	2.22^{abc}	469.40^{bc}	593.10^{bc}	262.80^{c}	271.90^{c}	3.69^{c}	4.05^{c}
Pendimethalin *fb* Ethoxy	2.14^{bc}	2.21^{abc}	462.40^{cd}	572.10^{cd}	259.40^{c}	268.20^{cd}	3.58^{c}	3.84^{cd}
Bispy tank mix with Ethoxy	2.13^{bc}	2.19^{abc}	442.40^{cde}	558.30^{cd}	255.10^{c}	267.50^{cd}	3.34^{d}	3.68^{d}
Pend *fb* tank mix of Bispy and Ethoxy	2.30^{ab}	2.31^{ab}	495.10^{b}	609.50^{b}	289.50^{b}	299.40^{b}	3.98^{b}	4.38^{b}
LSD (P<0.05)	0.16	0.21	28.09	35.12	18.01	17.23	0.15	0.29
Seedbed preparation methods								
i. Stale seedbed	2.07	2.11	440.50	554.40	247.70	258.20	3.24	3.47
ii. Normal seedbed	2.04	2.10	437.10	550.20	246.90	253.40	3.25	3.45
LSD (P<0.05)	ns	ns	ns	ns	ns	ns	ns	ns
CV %	7.51	11.52	10.58	9.76	10.19	10.93	8.14	10.65
Grand mean	2.06	2.11	438.79	552.29	247.31	255.80	3.24	3.46

Note*: fb- followed by, means followed by the common letter/s within a column are not significantly different based on DMRT at P <0.05, LAI – leaf area index, DM – dry matter*

Pendimethalin *fb* tank mixture of Bispyribac sodium and Ethoxysulfuron recorded significantly highest net return which was statistically at par with weed free treatment in both the years 2016 and 2017 while it was also statistically at par with Pendimethalin *fb* Bispyribac sodium in 2017. Higher net returns were the result of higher grain and straw yield (Rajaput, 2013). Chakraborti *et al.*, (2017) reported the lowest net return from weedy check treatment which was due to greater rice-weed competition resulting in poor growth of the crop. All the weed management treatments recorded a significantly higher B:C ratio over weedy check treatment (Table 3). Significantly, the highest B:C ratio was recorded with Pendimethalin *fb* tank mixture of Bispyribac sodium and Ethoxysulfuron in both the years. This was statistically at par with Pendimethalin *fb* Bispyribac sodium and Pendimethalin *fb* Ethoxysulfuron in 2016 and Pendimethalin *fb* Bispyribac sodium, Pendimethalin *fb* Ethoxysulfuron and Bispyribac sodium tank mix with

Ethoxysulfuron in 2017. Highest B:C ratio in these treatments was due to higher weed control efficiency, lower weed index, higher yield and low cost of cultivation due to saving of labor cost. Effect of seedbed preparation methods on gross return, net return and B:C ratio was not significant.

Table 3. Economic analysis as influenced by weed management practices and seedbed preparation methods of DDSR during 2016-2017, Parwanipur, Bara, Nepal

Treatments	Total cost NRs /ha ('000)		Gross return NRs /ha ('000)		Net return NRs /ha ('000)		Benefit cost ratio	
	2016	2017	2016	2017	2016	2017	2016	2017
Weed management practices								
Weed free	67.42	74.51	131.10^{a}	143.8^{a}	63.64^{a}	69.24^{a}	1.94^{c}	1.93^{bc}
Weedy check	46.42	50.51	58.64^{g}	52.07^{f}	12.22^{f}	1.55^{e}	1.26^{e}	1.04^{e}
Pendimethalin (Pend)	51.78	56.40	82.18^{f}	77.38^{e}	30.40^{e}	23.92^{d}	1.58^{d}	1.44^{d}
Sodium Bispyribac (Bispy)	51.16	55.58	98.53^{e}	104.9^{d}	47.37^{d}	49.28^{c}	1.93^{c}	1.89^{c}
Ethoxysulfuron (Ethoxy)	49.43	53.81	97.61^{e}	102.8^{d}	48.19^{d}	48.97^{c}	1.97^{bc}	1.91^{bc}
Pendimethalin *fb* Bispy	56.52	61.47	115.40^{c}	126.6^{b}	58.93^{b}	65.09^{ab}	2.04^{ab}	2.06^{ab}
Pendimethalin *fb* Ethoxy	54.79	59.70	113.30^{c}	119.9^{bc}	58.49^{b}	60.22^{b}	2.07^{ab}	2.01^{abc}
Bispy tank mix with Ethoxy	52.77	57.28	105.80^{d}	115.9^{c}	53.06^{c}	58.61^{b}	2.01^{bc}	2.03^{abc}
Pend *fb* tank mix of Bispy and Ethoxy	58.13	63.17	123.00^{b}	136.3^{a}	64.91^{a}	73.14^{a}	2.12^{a}	2.16^{a}
LSD (P<0.05)			4.38	7.78	4.38	7.79	0.08	0.13
Seedbed preparation methods								
Stale seedbed	57.06	62.16	102.90	109.10	45.88	47.60	1.79	1.75
Normal seedbed	51.48	56.16	102.80	108.60	51.28	52.41	1.98	1.91
LSD (P<0.05)			ns	ns	ns	ns	ns	ns
CV %			7.47	9.19	15.82	20.01	7.84	9.50
Grand mean			102.84	108.83	48.57	50.00	1.88	1.83

Note: *fb- followed by, means followed by the common letter/s within a column not significantly different based on DMRT at P <0.05*

Conclusions

Pendimethalin *fb* tank mixture of Bispyribac sodium and Ethoxysulfuron treated plots recorded highest weed control efficiency and lower weed index with higher values of growth attributes, yield, gross return, net return and B: C ratio other than weed free check treatment in dry direct-seeded rice. The effect of seedbed preparation methods however was not significant.

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