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Evaluation of Herbicides Efficacy to Control the Complex Weed Flora of Dry Direct Seeded Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration between both authors. Author RS designed the study, wrote the protocol and wrote the first draft of the manuscript. Author VPS supervised the experiment and brought the manuscript in final mode by correct and update it. Both authors read and approved the final manuscript.

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ABSTRACT

First thing which strike in researcher's mind whenever they talk about dry direct seeded rice (DSR) is weed, no doubt Dry DSR is a promising resource conservation technology (RCT) but its acceptance among rice growers is obstructed due to heavy weed conquest. A field study was conducted at GBPUAT, Pantnagar to evaluate the efficacy of herbicides to control the complex weed flora of Dry DSR (*Oryza sativa* L.). Total ten herbicides were evaluated in the experiment which were consisted application of Pyrazosulfuron 25, Pretilachlor 750, Chyhalofop butyl 90, Fenoxaprop 60, Cyhalofop butyl +(chlorimuron + metsulfuron) 90+20, Fenoxaprop +(chlorimuron + metsulfuron) 60+20, Azimsulfuron 35, Bispyribac sodium 25, Fenoxaprop +Ethoxysulfuron 60+15 and Oxyflurofen + 2,4-D 300+500 g ha^{-1} respectively. Grassy weeds dominant the field throughout the growing season. Up to 60 days after sowing (DAS) sedge share 25-30% in total weed population

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in weedy plot, but later on grassy weeds surpass and maintain above 85% of total weed share up to harvest. Among different herbicides Fenoxaprop +Ethoxysulfuron 60+15 recorded highest weed control efficiency (91.9%) followed by Fenoxaprop +(chlorimuron + metsulfuron) 60+20 (85.6%) and Bispyribac sodium 25 g ha^{-1} (85.4%) at 60 DAS. Pre-emergence herbicides like Pyrazosulfuron 25, Pretilachlor 750 and Oxyflurofen + 2,4-D 300+500 g ha^{-1} were not found effective to control weeds and face heavy weed infestation from very early stage of crop. Post-emergence herbicides like as Fenoxaprop +(chlorimuron + metsulfuron) 60+20 recorded the highest grain yield (34.01 q ha^{-1}) followed by Fenoxaprop +Ethoxysulfuron 60+15 (31.78 q ha^{-1}) and Bispyribac sodium 25 g ha^{-1} (31.75 q ha^{-1}) which were at par with two hand weeding (32.63 q ha-1) and Pyrazosulfuron at 25 (4.42 q ha^{-1}) Pretilachlor 750 g ha^{-1} (4.38 q ha^{-1}) gave non-significant yield increase over the weedy (4.16 q ha^{-1}) plot.

Keywords: Evaluation; dry direct seeded rice; weed control; herbicides efficacy.

1. INTRODUCTION

Transplanted rice is the widespread practice of rice cultivation in world and also in Indo Gangetic Plains (IGP) of India. Transplanted rice is a key user of fresh water and is highly disorganized in its use efficiency. Rice consumes about half of total irrigation water used in Asia [1] and accounts for about one third of the world's irrigation water [2]. On an average, 2500 l of water are required, ranging from 800 to more than 5000 l, to produce 1 kg of rough rice [3]. In present era of energy crisis and fragile ecosystem transplanted rice not a feasible practice to sustain rice productivity and profitability for long term and high demand for water limiting to bring new area under rice cultivation. Transplanted rice have constraint of late planting, high cost of production, high methane emission from puddled field, restricted root system and adverse effect on soil physical properties due to intensive tillage under ponded-water, which affects the follow crop. Transplanted rice and succeeding crops mainly wheat have diverse edaphic requirements, annual conversion of soil from aerobic to anaerobic conditions for transplanted rice and then back to aerobic conditions for succeeding crop a big threat for sustainability of food production system [4]. Rice production system are undergoing numerous changes in establishment methods of rice cultivation and one of such alternative is direct dry or wet seeding of rice. Direct seeding of rice by either dry or wet establishment methods is spreading rapidly in Asia particularly Philippines, Malaysia and Thailand as the farmers search for high productivity and profitability to offset mounting cost and paucity of farm labour [5]. Dry direct seeding of rice establishment method offer several advantages i.e. water saving of 11-18% in irrigations [6], reduces total labour requirement (11-66%) compared to puddeled transplanted rice (PTR) [7], timely sowing, less drudgery, early crop maturity (7-10 days), high acceptance to water shortfall, low production cost and higher net profit, better soil physical condition to following crops and less methane emission than the transplanting [8].

Despite several advantages higher numbers, diverse weed flora and long critical period (15-45 day after seeding) as compared to transplanted rice [9] in Dry-DSR is the principal biological constraint limiting their productivity and a hurdle in adoption of this resources conservation technology (RCT) among rice grower. Weed control failure in Dry DSR cause yield losses ranging from 50 to 90% [10].

Dry DSR crop lacks a "head start" over weeds due to dry tillage, absence of standing water and alternate wetting and drying condition make it defenseless to encounter with weed during early part of its growth [11]. As the weeds and rice emerge simultaneously in Dry DSR, the proper time and method of weed control remains a complex phenomenon [12]. Our farmers forced to depend on conventional method of rice crop establishment because still weed control issue not addressed thus, reducing the profitability and sustainability. An effective weed control tactic is mandatory for any DSR production technology to achieving higher productivity, profitability and adaptability among growers [13]. The present work is intended to address the weed control issue through evaluate suitable herbicides and time of application in Dry DSR.

2. MATERIALS AND METHODS

2.1 Experimental Field Description

The experiment was carried out during the *Kharif* season of 2010 in D_2 block of N.E Borlaug, Crop

Research Centre of GBPUAT, Pantnagar, District Udham Singh Nagar, Uttarakhand, India. Pantnagar falls in sub-humid and subtropical climatic zone and situated in *Tarai* belt of Shivalik range of foot hills of Himalayas. Geographically it is located at 29 ° N latitude and 79.29 ° E longitudes and an altitude of 243.84 meter above mean sea level. The climate of Pantnagar is humid subtropical with hot and dry summer, cold winters and heavy rains in rainy season (June to September). Generally, the mean maximum temperature during hottest months (May and June) varies from 33.2 to 38.4 ℃ and mean minimum temperature during coldest months (December to January) varies from 5.0 to 8.8 ℃. The mean annual rainfall is 1364 mm in which 80-90% is normally received during June to September. Mean maximum temperature ranged from 28.2℃ in June to 39.9℃ in October during 2010. The mean minimum temperature ranged from 14.5℃ in October to 26.7℃ in June. The relative humidity ranged from 58 to 95% recorded at 7.00 am and from 31 to 84% recorded at 2.00 pm during the crop growing period. The average weekly rainfall received during the crop growing period was 83.55 mm. The soil of *Tarai* region are developed from calcareous, medium to moderately coarse textured materials under predominant influence of tall vegetation and moderate to well drained conditions.

The soil of the experimental plot D_2 was loam in texture. The experimental plot was high in organic carbon (0.81), medium in available phosphorus (21.62 kg ha^{-1}) and available potassium (141.92 kg ha^{-1}), low in available nitrogen (215.61 kg ha^{-1}) with neutral p^H (7.2).

2.2 Experimental Design

The experiment laid out in randomized block design (RBD) with replicated thrice consisted of 12 treatments detail given in Table 1. Gross plot size was: 5 m x 3 m (15 m^2) and net plot size: 4 m x 1.6 m (6.4 m^2) under the experiment. The field was evenly dry-seeded manually in line 20 cm apart with 40 kg of seed ha^{-1} (Narendra-359, Indica rice) on 9th June 2010 and harvested on 21st October 2010 (135 DAS). The experimental crop was fertilized with 150: 60: 40 kg ha^{-1} of N, P & K respectively. Nitrogen was applied through NPK mixture (12:32:16) and rest amount of nitrogen through urea. The total amount of phosphorus and potassium was applied through NPK mixture (12:32:16). Full quantity of phosphorus and potassium and one third of nitrogen was applied in opened furrow just before sowing of rice seed. Remaining half of the nitrogen was top dressed through urea in two splits; first at active tillering and second at panicle initiation stage. Herbicides were applied as aqueous medium at the rate of 750 liters water ha^{-1} for post emergence herbicide and 1000 liters for pre emergence herbicide with help of *Maruti* foot sprayer fitted with flat fan nozzle. The amount of herbicides and water required was computed on the basis of gross plot size to be treated.

2.3 Observation and Sampling Procedures

For observation, the sampling area was fixed in each plot. On one side of each plot, one meter row length of crop from third row was marked for observation like plant height, number of shoots and post harvest studies on the crop.

Table 1. Detail of treatment used in experiment

Sl. no.	Treatment	Dose (g a.i.ha^{-1})	Application DAS*
1.	Pyrazosulfuron	25	3
2.	Pretilachlor	750	3
3.	Chyhalofop butyl	90	30
4.	Fenoxaprop	60	30
5.	Chyhalofop butyl + (chlorimuron + metsulfuron)	90+20	30
6.	Fenoxaprop +(chlorimuron + metsulfuron)	60+20	30
7.	Azimsulfuron	35	20
8.	Bispyribac sodium	25	20
9.	Fenoxaprop +Ethoxysulfuron	60+15	30
10.	Oxyflurofen + 2,4-D	300+500	3 fb 30
11.	Two hand weeding	-	20&40
12.	Weedy		

** DAS = days after sowing*

On other side of the plot, leaving two border rows, the areas of third and fourth row was used for observation on weeds and crop dry matter accumulation. Weeds were recorded species wise in each plot at 30, 60, 90 and 120 days after sowing using quadrate of 50 cm x 50 cm from the area marked for observation. The count was expressed as number of weeds m^{-2}. All the weed species falling within the quadrate were cut close to the ground surface at 30, 60, 90 and 120 DAS dried in a hot air oven maintained at 70℃ till constant dry weight. Dry matter of total weeds at 30 DAS and species wise at 60, 90 and 120 DAS was recorded and expressed in g m^{-2}. Weed control efficiency (WCE) of different treatments was calculated on the basis of reduction in weight in treated plot in comparison to weedy check and expressed as percentage. The gross plot (5.0 m $\times$ 3.0 m) 15 m^2 had 15 rows, out of which only 8 rows were harvested, remaining rows left as border row. Out of 5.0 m row length 0.5 m length from both sides was left for border effect, so that harvesting of net plot of (4.0 m $\times$ 1.6 m) 6.4 m^2 area done by manually. The number of panicles was counted from the sampling area of one meter row length before harvesting. Ten panicles were randomly selected from the one meter row length than manually threshed and number of total grains was counted. The number of grain per panicles was computed by averaging all the ten panicles. The weight of grain harvested from the net plot area was recorded in kg and computed as q ha^{-1}. The weight of the total produce per net plot was recorded before threshing. The straw yield was computed by subtracting the grain yield from the weight of total produce of the net plot and expressed as q ha^{-1}.

The data on different characters were analyzed by using analysis of variance technique for Randomized Block Design (RBD) as suggested by [14]. Standard error of mean difference at 5 percent level of probability was calculated for significant effects. Weed population, weed dry matter and nutrient uptake by weeds were analyzed after doing log (X + 1) transformation as suggested by [15]. Original values in data related to weeds are given in parenthesis.

3. RESULTS AND DISCUSSION

Major weed species observed in experiment field was *Echinocola colon, Echinocola crusgallii,* and *Leptochloa chinesis* among grassy, *Caesulia axillaris, Trianthama protulaca and Cyperus rotundus* among broad leaf and sedges. Highest weed density in weedy plot recorded at 30 days stage and decreased at later stages of crop growth. The rate of decrease in weed density on an average was 3.07 weeds m^{-2} day^{-1} from 30 to 60 days and 1.43 weeds m^{-2} day^{-1} from 60 to 90 days but thereafter the weed population was established. This indicated that competition among weeds themselves and with the crop plants deciding factor at later stage.

Total weed dry matter production increased in all the treatment up to the 90 DAS and then after slightly decreased. The rate of dry matter production of weeds in weedy treatment was 1.43, 13.91 and 14.23 g m^{-2} day^{-1} during 0 to 30, 30 to 60 and 60 to 90 days, dry matter accumulation rate g m^{-2} day^{-1} was highest from 60 to 90 days but dry matter accumulation rate per gm of previous dry matter was highest during 30 to 60 days which were 10.37 times as compared to 1.93 times during 60 to 90 days. This indicates that in case of Dry DSR the critical period of crop-weed competition was from 15 to 60 days. The similar result has also been reported by [16].

Relative density of weeds (Table 2) in weedy plot clearly indicate that in dry seeding grassy weeds dominate throughout the growing season and very robust in nature they suppress crop as well as other broad leaf and sedges also. Grassy weeds constituted 59.6, 57.8, 87.9 and 86.6 per cent of total weed population at 30, 60, 90 and at harvest stages respectively. Up to 60 DAS sedge share 25-30% in total weed population in weedy plot, but later on grassy weeds surpass and maintain above 85% of total weed share till crop harvest. The dominate weed species were *E. colona*, *P. maxicum*, *C. axillaris*, *L. chinesis, T. protulaca, E. crusigalli*, and *C. rotundus* which constituted 36.3, 14.5, 5.8, 1.2, 2.9, 5.8 and 31.8 per cent of total weed population respectively (Table 3) and 90.72, 1.1, 0.7, 1.86, 0.4, 3.28 and 2.34 per cent of total weed dry matter production at 60 days stage, respectively (Table 4). Data clearly showed that *E. colona* more vigorous in nature among grassy weed also and it suppress crop as well as other weed species as growing season proceed. Predominance of *E. colona* in Dry DSR has also been reported by [17].

Among different herbicides Fenoxaprop +Ethoxysulfuron 60+15 recorded highest weed control efficiency (91.9%) followed by Fenoxaprop +(chlorimuron + metsulfuron) 60+20 (85.6%) and Bispyribac sodium 25 g ha^{-1} (85.4%) at 60 DAS which was as effective two hand weeding with 94.1 percent (Fig. 1). Fenoxaprop 60, Bispyribac sodium 25, Azimsulfuron 35 g ha^{-1} alone and in combination was very effective to control *E. crusgalli* same result has also been reported by [18,19]. Application of Azimsulfuron 35 g ha^{-1} was not found effective to control the *L. chinesis* and the population increase with later stages of crop growth as compared to 30 DAS.

Table 2. Relative density of weeds in weedy plot at different stages of crop growth

Days stage	Grassy weeds				Grassy total	Broad leave weeds		BLW total	Sedges	Whole total
	E. colona	***E. crusigalli***	***P. maxicum***	***L. chinesis***		***C. axillaris***	***T. protulaca***		***C. rotundus***	
30	39.3	0.0	5.1	15.2	59.6	0.0	13.8	13.8	26.1	100
60	36.3	5.8	14.5	1.2	57.8	5.8	2.9	8.7	31.8	100
90	66.7	12.1	9.1	0.0	87.9	2.9	0	2.9	9.1	100
120	50.0	23.3	0	13.3	86.6	13	0	13	0.0	100

Table 3. Effect of treatments on total weed density (No m^{-2}) at different stage of crop growth

Treatment	Stages (Days after sowing)			
	30	**60**	**90**	**120**
Pyrazosulfuron	5.19(180)	4.3(74.7)	3.6(36.0)	3.6(36.0)
Pretilachloar	4.5(89.3)	4.2(66.7)	3.3(26.7)	3.6(36.0)
Cyhalofop butyl	4.92(136)	4.97(143.3)	3.2(24.0)	3(18.7)
Fenoxprop	4.08(58.6)	4.3(76.0)	3(18.7)	2.3(9.3)
Cyhalofopbutyl + (chlorimuron+metsulfuron)	4.13(61.3)	4.7(108.7)	3.5(33.3)	3.2(24.0)
Fenoxprop + (chlorimuron+metsulfuron)	4(56.0)	4.1(60)	2.6(13.3)	2.2(8.0)
Azimsulfuron	3.45(32.0)	3.4(29.3)	3.3(25.3)	2.8(16.0)
Byspiribac sodium	3.16(22.6)	3.7(40.0)	2.3(9.3)	1.8(5.3)
Fenoxprop+Etoxysulfuron	4.04(57.4)	4.3(73.3)	2.9(17.3)	2.6(12.0)
Oxyfluron + 2,4-D	4.66(105.3)	4.8(125.3)	3(20.0)	3(20.0)
Two hand weeding 20 & 40 days	3.86(46.7)	3.4(29.3)	3.4(28.0)	2.8(16.0)
Weedy	5.2(184)	4.5(92.0)	3.9(49.3)	3.7(40.0)
S.Em.±	0.11	0.08	0.09	0.09
LSD (P=0.05)	0.34	0.25	0.27	0.27

Note: Original values are given in parenthesis

Table 4. Effect of treatments on total dry matter of weeds (g m^{-2}) at different stage of crop growth

Treatment	Stages (Days after sowing)			
	30	**60**	**90**	**120**
Pyrazosulfuron	20	296.27	525.6	554.8
Pretilachloar	18.13	247.73	510.8	396.53
Cyhalofop butyl	12.67	142.27	286.8	136.93
Fenoxprop	8.53	118	117.07	122
Cyhalofopbutyl + (chlorimuron+metsulfuron)	10.93	130.67	270.47	228
Fenoxprop + (chlorimuron+metsulfuron)	9.59	66.8	102.93	119.33
Azimsulfuron	3.73	66.4	105.33	171.47
Byspiribac sodium	3.2	65.33	49.7	89.73
Fenoxprop+Etoxysulfuron	5.73	35.2	106.3	114.27
Oxyfluron + 2,4-D	9.59	186.47	384.27	425.2
Two hand weeding 20 & 40 days	2.93	25.47	37.27	87.4
Weedy	42.93	460.4	887.33	589.07
S.Em.±	1.2	8.36	10.9	20.1
LSD (P=0.05)	3.54	24.53	32.01	58.86

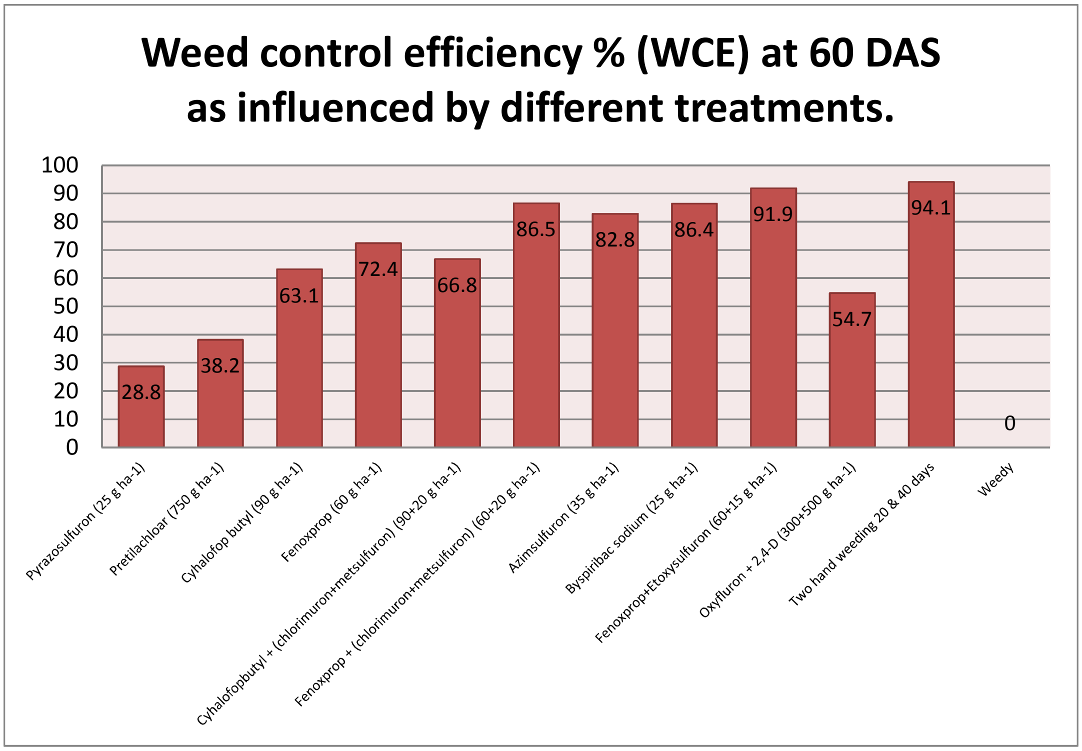

Fig. 1. Weed control efficiency % (WCE) at 60 days stage as influenced by different treatments

Table 5. Effect of different treatments on yield attribute, grain, straw yield and grain/straw ratio

Treatment	Number of panicle (m^{-2})	Number of grains/panicle	1000-grain weight	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Grain/ straw ratio
Pyrazosulfuron	38.3	144.0	23.93	4.42	18.11	0.26
Pretilachloar	31.7	116.0	21.29	4.38	16.97	0.26
Cyhalofop butyl	113.3	151.0	22.65	14.16	36.87	0.39
Fenoxprop	118.3	165.0	24.16	27.66	50.44	0.57
Cyhalofopbutyl + (chlorimuron+metsulfuron)	115.0	134.0	23.44	15.36	38.01	0.41
Fenoxprop + (chlorimuron+metsulfuron)	161.7	153.0	22.12	34.01	56.89	0.62
Azimsulfuron	176.7	150.0	24.19	20.83	59.37	0.37
Byspiribac sodium	166.7	176.0	24.45	31.75	53.94	0.60
Fenoxprop+Etoxysulfuron	151.7	146.0	24.31	31.87	53	0.59
Oxyfluron + 2,4-D	68.3	126.0	21.14	12.08	26.98	0.46
Two hand weeding 20 & 40 days	165.0	157.0	25.26	32.63	54.01	0.61
Weedy	33.3	109.0	20.73	4.16	16.67	0.25
S.Em.±	9.7	10.47	0.85	2.2	5.03	0.07
LSD (P=0.05)	28.55	30.72	2.5	6.54	14.7	0.2

Weedy plot caused up to 87.76% reduction in grain yield. All the weed control treatment gave significantly higher grain yield over the weedy check, except application of Pretilachlor 750 and Pyrazosulfuron 25 g ha^{-1} (Table 5). Fenoxaprop +(chlorimuron + metsulfuron) 60+20 recorded the highest grain yield (34.01 q ha^{-1}) followed by Fenoxaprop +Ethoxysulfuron 60+15 (31.78 q ha^{-1}) and Bispyribac sodiumat 25 g ha^{-1} (31.75 q ha^{-1}) which at par with two hand weeding (32.63 q ha^{-1}). The higher grain yield in above treatment was mainly attributes to effectively control of weeds from early stage of crop growth. However application of Pyrazosulfuron 25 (4.42 q ha^{-1}) and Pretilachlor at 750 g ha^{-1} (4.38 q ha^{-1}) which could not reach up to the significant level over the weedy (4.16 q ha^{-1}) and the lower grain yield in these treatment was mainly attributes to lower number of panicles and number of grains per panicle which were consequence of competition due to higher weed density and dry matter accumulation of the weeds. Grain to straw also indicate that if weed not control at early stage than it gave tough competition to the yield attributing character and crop can't reach to satisfactory yield level.

Pre-emergence herbicides like Pyrazosulfuron 25, Pretilachlor 750 and Oxyflurofen + 2,4-D 300+500 g ha^{-1} were not found effective to control weeds and face heavy weed infestation from very early stage of crop. Post-emergence herbicides like as Fenoxaprop +(chlorimuron + metsulfuron) 60+20, Fenoxaprop +Ethoxysulfuron 60+15 and Bispyribac sodium 25 g ha^{-1} was very effective to control the weeds and as effective as two hand weeding.

Dry DSR recorded low yield as compare to TPR because of poor crop establishment (not uniform germination) and crop maturity also not synchronized. In Dry DSR chances of brown plant hopper (BPH) infestation at panicle initiation also high because crop spacing not uniform like as TPR, so some time in case of robust plant growth air circulation is poor and good plant growth favorable for BPH attack so regular vigilance at panicle initiation desirable. Dry DSR still require many technology standardization like as the seed rate, spacing, nutrient application, water management and weed management to compete with TPR in terms of yield point of view. Among above agronomic practices weed management is at top priority without it no other agronomic strategic work so above study useful to understand this factor of crop production in Dry DSR.

4. CONCLUSION

One thing clears that long critical period in Dry DSR so single application of presently available pre emergence herbicides not sufficient to combat weed issue in Dry DSR.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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