Research Article

WEED DYNAMICS AND PRODUCTIVITY OF DRY DIRECT SEEDED RICE IN RELATION TO TILLAGE AND WEED MANAGEMENT PRACTICES

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ABSTRACT

Weed is one of the major constraints for success of dry direct seeded rice (DDSR) technology. The productivity, weed density and weed dry weight of DDSR is influenced by weed management practices. A field experiment was done to evaluate tillage methods and weed management practices on weed dynamics and yield of DDSR using split plot design; each treatment replicated thrice. The treatment consisted of two tillage methods in the main plots, and eight weed management practices in the sub-plots. Gorakhnath-509 was the variety of rice used.Weed flora observed in the experiment comprised of 25 weed species, belonging to 12 families. Among them 12 were broadleaf weed, belonging to 10 families; 8 were grasses, belonging to Poaceae family, and the rest 5 were sedges, belonging to Cyperaceae family. Tillage methods did not influence weed density and weed dry weight in DDSR, but weed management practices reduced weed density and dry weight at all dates of observation compared to weedy check. All the weed management practices significantly improved the grain yield of DDSR in both tillage methods. Treatments with higher grain yield of DDSR were, use of pendimethalin followed by hand weeding (3,742 kg ha^{-1}); pendimethalin followed by bispyribac-Na (3,552 kg ha^{-1}), and pendimethalin followed by tank mixture application of bispyribac-Na and ethoxysulfuron(3,638 kg ha^{-1}), but were statistically similar ($p>0.05$). Results thus supports the fact that application of popular pre-emergence herbicide- pendimethalin followed by manual weeding, or post-emergence herbicide, such as Bispyribac-Na, or tank mixture of post emergence herbicides bispyribac-Na and Ethoxysulfuron could be the most effective weed management practices in both tillage method of rice cultivation.

Key words: DDSR, tank mixture, weed dynamics, yield

INTRODUCTION

Rice is one of the important food crops in Nepal. The area under rice cultivation accounts 1.46 million ha with the total production of 5.13 million t and average productivity of 3.35 t ha^{-1} (MOALD, 2017). Rice in Nepal is planted mainly by two principal methods i.e. transplanting, and direct seeding. Direct seeded rice is an alternative to transplanting system of rice production. Dry Direct Seeded Rice (DDSR) is becoming an attractive option for farmers as it requires much less labor and establishment cost than manually transplanted rice (Devkota et al., 2014). Direct-seeding is cost effective, can save water through earlier rice crop establishment, and allows early sowing of wheat in the standard cropping system (Kumar et al., 2015). Kumar & Ladha (2011) has reported several benefit of this system that could address with the condition of increasing water scarcity, labor shortage, and increased cost of labor. These scenarios have developed good chance of crop intensification through DDSR method which is equally important to consider from the perspective of promoting conservation agriculture.

Crop in DDSR is subjected to greater weed competition than in puddled transplanting because emerging DDSR seedlings are less competitive with concurrently emerging weeds and the initial flush of weeds is not controlled by flooding in Wet and Dry DSR (Rao et al., 2007). In the absence of effective weed control options, yield losses are greater in DDSR than in transplanted rice (Baltazar & De Datta, 1992). Therefore, heavy weed infestation is a major problem in direct seeded rice and its success lies in implementation of effective weed control measures (Kumar et al., 2015), as failure to eliminate weeds may result in low or no yield (Estoninos & Moody, 1988). Under this context an experiment was done to evaluate tillage methods and weed management practices on weed dynamics and yield of DDSR so as to establish best weed control method.

MATERIAL AND METHODS

The experiment was done at Agronomy Farm of Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal during June 2016 to October 2016. The field was under zero tillage in rice-wheat cropping system for previous three years. The soil of experimental site was slightly acidic (5.81) with sandy loam texture. The total precipitation recorded during the experiment was 1707.60 mm.

The experiment was done by using a split-plot design with three replications. The treatment consisted of two tillage methods i.e. Zero Tillage (ZT) and Conventional Tillage (CT) in main plots, and eight weed management practices in the sub plots:

WMP_1 = Weedy check

WMP_2 = Weed free
WMP_3 = Pendimethalin followed by Hand weeding
WMP_4 = Pendimethalin followed by 2, 4-D ethyl ester
WMP_5 = Pendimethalin followed by Bispyribac-Na
WMP_6 = Pendimethalin followed by Penoxsulam
WMP_7 = Pendimethalin followed by Ethoxysulfuron
WMP_8 = Pendimethalin followed by (Bispyribac-Na + Ethoxysulfuron)

The size of the individual plot was 22.4 m^2, consisting of 35 rows with 20 cm spacing. The rice variety used was Gorakhnath-509 with the seed rate of 50 kg ha^{-1}. 120: 80: 60 kg NPK ha^{-1}, respectively, was used along with Zinc sulphate, 25 kg ha^{-1}.

Weeds were managed as per the treatments. Weedy check was left weedy and weed free was kept devoid of weeds throughout the growing period. Hand weeding was done at 35 Days after sowing (DAS). Respective herbicides were applied with the help of calibrated knap sack sprayer at specified dates with recommended doses.

Table 1. Herbicides used with their recommended dose, available form, and application time

Herbicides	Recommended dose	Available form	Application time
Glyphosate	1000 g a.i ha^{-1}	47 % SL	15-20 days before sowing
Pendimethalin	1000 g a.i ha^{-1}	30 % EC	1-3 DAS
2,4-D ethyl ester	500 g a.i. ha^{-1}	38 % EC	15-25 DAS
Bispyrabic-Na	25 g a.i ha^{-1}	10 % SC	15-25 DAS
Phenoxsulam	22.5 g a.i ha^{-1}	24 % SC	15-20 DAS
Ethoxysulfuron	83.3 to 100 g a.i ha^{-1}	15 % WG	15-20 DAS

Weed sampling for weed identification, weed density and dry weight determination was done at every 15 days interval starting from 15 DAS to 60 DAS. All the agronomic data were taken using standard techniques. The data on weeds was transformed by square root transformation. ANOVA was done and significant data were subjected to DMRT for mean comparison (Gomez & Gomez, 1984).

RESULTS AND DISCUSSION

Weed flora

The dominant weeds recorded at different growth stages of DDSR plots are listed in Table (2).

Table 2. Weeds observed in DDSR plots at AFU, Rampur, Chitwan, 2016

Scientific Name	Common name	Family	Class	Habit
Grasses				
Cynodon dactylon (L.) Pers.	Bermuda grass	Poaceae	M	PH
Digitaria ciliaris (Retz.) Koeler	Crab grass	Poaceae	M	AH
Digitaria setigera Roth ex Roem. & Schult.	Crab grass	Poaceae	M	AH
Echinochloa colona (L.) Link	Barnyard grass	Poaceae	M	AH
Echinochloa crus-galli (L.) P. Beauv.	Barnyard grass	Poaceae	M	AH
Eleusine indica (L.) Gaertn.	Goose grass	Poaceae	M	AH
Paspalum scrobiculatum L.	Kodo millet	Poaceae	M	AH
Setaria glauca (L.) P. Beauv.	Yellow foxtail	Poaceae	M	PH
Sedges				
Cyperus compressus L.	Poor land flat sedge	Cyperaceae	M	AH
Cyperus difformis L.	Small-flowered nutsedge	Cyperaceae	M	AH
Cyperus iria L.	Rice flat sedge	Cyperaceae	M	AH
Fimbristylis miliacea (L.) Vahl	Hoorah grass	Cyperaceae	M	PH
Scirpus juncoides Roxb.	Rice field bulrush	Cyperaceae	M	PH

Broad leaf weeds				
Ageratum conyzoides L.	Goat weed	Compositae	D	AH
Oxalis corniculata L.	Creeping wood sorrel	Oxalidaceae	D	PH
Centella asiatica (L.) Urb.	Spade leaf	Apiaceae	D	PH
Commelina benghalensis L.	Day flower	Commelinaceae	M	PH
Cleome viscosa L.	Spider weed	Cleomaceae	D	AH
Aeschynomene indica L.	Joint vetch	Fabaceae	D	PH
Alternanthera sessilis (L.) R. Br.	Sessile joy weed	Amaranthaceae	D	PH
Eclipta prostrata (L.)	False daisy	Compositae	D	AH
Ludwigia octovalvis (Jacq.) P.H. Raven	Mexican primrose-willow	Onagraceae	D	PH

Note: A, Annual; P, Perennial; H, Herb; M, Monocot; D, Dicot.

Twenty-five weed species belonging to twelve families were recorded in the experimental plots. All the grassy weeds were monocots and belong to Poaceae family. Similarly, all the sedges were from Cyperaceae family and monocot. The broad leaved weeds observed included ten different families and dicot, except *Commelina benghalensis*.

Weed density and dry weight

Table 3. Total weed density (number of weeds m^{-2}) in relation to tillage methods and weed management practices in DDSR plots at AFU, Rampur, Chitwan, 2016

Treatments	Total weed density (number of weeds m^{-2})			
	15 DAS	**30 DAS**	**45 DAS**	**60 DAS**
Tillage				
ZT	18.41(427.71)	20.49(480.83)	11.15(169.27)	9.48(107.92)
CT	15.60(301.04)	17.61(364.9)	10.53(131.98)	8.94(87.81)
SEm (±)	0.98	0.93	0.47	0.98
LSD (=0.05)	NS	NS	NS	NS
CV, %	10	8.4	7.5	18.4
Weed management practices				
WMP_1	28.79^{a}(874.17)	30.17^{a}(991.25)	23.38^{a}(572.08)	14.84^{a}(230.83)
WMP_2	23.67^{ab}(556)	19.92^{b}(408.75)	7.27^{b}(68.33)	8.07^{b}(68.33)
WMP_3	12.75^{c}(168.33)	14.22^{b}(210.83)	9.87^{b}(98.33)	6.69^{b}(46.25)
WMP_4	16.98^{bc}(383.33)	18.73^{b}(378.75)	10.87^{b}(120)	9.55^{b}(96.25)
WMP_5	13.85^{c}(236.67)	17.45^{b}(422.92)	9.21^{b}(98.75)	8.79^{b}(102.5)
WMP_6	17.23^{bc}(391.67)	20.89^{b}(465.83)	9.27^{b}(100.83)	9.23^{b}(92.08)
WMP_7	10.25^{c}(110.83)	16.14^{b}(270.83)	8.38^{b}(72.92)	9.90^{b}(97.92)
WMP_8	12.55^{c}(185)	14.91^{b}(233.75)	8.45^{b}(73.75)	6.63^{b}(48.75)
SEm (±)	2.77	2.56	1.20	1.16
LSD (=0.05)	8.011	7.40	3.47	3.35
CV,%	39.8	32.8	27.1	30.80
Grand Mean	364.38	422.86	150.63	97.86

Note: Data subjected to square root ($\sqrt{}$X+0.5) transformation; figures in parentheses are original value; ZT, Zero Tillage; CT, Conventional Tillage; ns, Non-significant at p<0.05 ; BLW, broadleaf weed; Treatment means followed by common letter(s) are not significantly different (p>0.05)

Table 4. Weed dry weight (g m^{-2}) in relation to tillage methods and weed management practices in DDSR plots at AFU, Rampur, Chitwan, 2016

Treatments	Weed dry weight (g m^{-2})			
	15 DAS	**30 DAS**	**45 DAS**	**60 DAS**
Tillage				
ZT	3.49(15.31)	7.04^{a}(62.33)	8.97(139.23)	8.88(106.11)
CT	3.07(9.65)	5.99^{b}(42.75)	8.88(112.25)	8.30(88.04)
SEm (±)	0.24	0.05	0.44	0.24
LSD (=0.05)	NS	0.30	NS	NS
CV, %	12.7	1.3	8.5	4.8
Weed management practices				
WMP_1	4.00^{ab}(17.17)	12.30^{a}(156.54)	22.37^{a}(514.17)	14.84^{a}(224.67)
WMP_2	4.98^{a}(30.33)	3.98^{c}(17.83)	1.53^{d}(4.08)	3.42^{d}(15.33)
WMP_3	2.50^{bc}(6.33)	5.00^{bc}(25.79)	5.00^{cd}(25.54)	3.86^{d}(15.88)
WMP_4	3.45^{abc}(12)	5.57^{bc}(34.58)	10.34^{b}(126.96)	10.65^{abc}(127.92)
WMP_5	3.16^{bc}(11.42)	5.78^{bc}(41.79)	6.66^{bcd}(56.04)	7.69^{cd}(65.83)
WMP_6	3.29^{bc}(11.17)	8.05^{b}(69.38)	10.94^{b}(142.54)	13.17^{ab}(179)
WMP_7	2.22^{c}(4.67)	6.05^{bc}(39.38)	8.49^{bc}(89.21)	8.90^{bc}(97.5)
WMP_8	2.64^{bc}(6.57)	5.39^{bc}(35.13)	6.10^{bcd}(47.38)	6.20^{cd}(50.5)
SEm (±)	0.52	1.00	1.64	1.51
LSD (=0.05)	1.52	2.91	4.75	4.37
CV,%	39.1	37.7	45	43
Grand Mean	12.48	52.54	125.74	97.08

Note: Data subjected to square root ($\sqrt{}$X+0.5) transformation; figures in parentheses are original value; ZT, Zero Tillage; CT, Conventional Tillage; ns, Non-significant at p<0.05 ; BLW, broadleaf weed; Treatment means followed by common letter(s) are not significantly different (p>0.05)

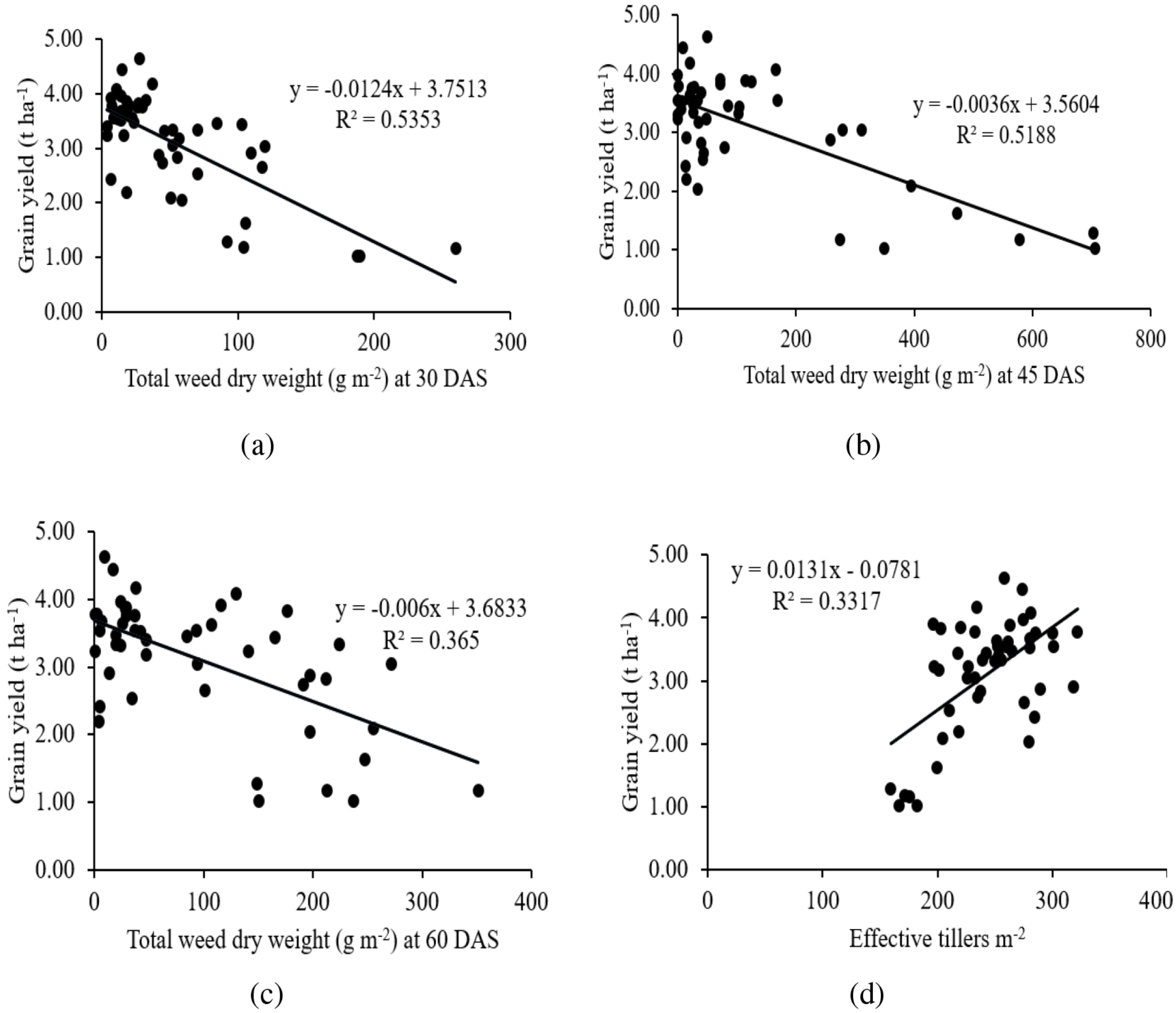

Figure 1. Relationship between (a) weed dry weight (g m^{-2}) and grain yield of DDSR at 30 DAS, (b) weed dry weight (g m^{-2}) and grain yield of DDSR at 45 DAS (c) weed dry weight (g m^{-2}) and grain yield of DDSR at 60 DAS, (d) effective tillers per square meter and grain yield of DDSR at 90 DAS at AFU, Rampur, Chitwan, 2016

The weed density at each observation was not influenced by tillage methods, and was higher in Zero tillage. At 15 DAS, weed density at weedy check plot was higher and was statistically at par with weed free plot. Weed density in pendimethalin applied plots were statistically at par with each other and were lower as compared to weed free and weedy check. At 30, 45 and 60 DAS, weed density at weedy check plot was significantly higher ($p<0.05$) as compared to all other weed managed plots (Table 3).

Tillage method was found to have significant influence on weed dry weight at 30 DAS. At 30 DAS weed dry weight at zero tillage was significantly higher ($p<0.05$). At 15,45 and 60 DAS weed dry weight was not influenced by tillage methods but the weed dry weight was found to be higher in zero tillage. Weed management practices significantly influenced the weed dry weight. At 15 DAS weed dry weight was significantly lower ($p<0.05$) in pendimethalin applied plots as compared to weedy check. All the weed management practices significantly reduced the weed dry weight in comparison with weedy check at 30, 45 and 60 DAS. Among the post emergence herbicides, bispyribac-Na and tank mixture application of bispyribac-Na and ethoxysulfuron was the best in controlling weeds (Table 4).

Govindan & Chinnusamy (2014), reported higher weed density and dry weight in zero tillage system and Feldman et al., (1997) stated that low soil disturbance in zero tillage system is likely to leave large portion of weed seed bank near the soil surface resulting in higher weed seedling emergence. The results clearly show significant reduction in weed density due to application of pendimethalin as pre- emergence herbicide. Goswami et al., (2017) also recorded lower weed density in pendimethalin applied treatments and stated that application of pendimethalin as pre-emergence can significantly reduce the weed density and dry weight in DDSR field. Application of weed management options followed by pre-emergence herbicide significantly reduces the weed density and dry weight. Successive application of pre and post emergence herbicides adequately controls weeds by widening the range of weed control (Mahajan et al., 2009). Among the post emergence herbicides, bispyribac-Na and tank mixture application of bispyribac-Na and ethoxysulfuron were best in controlling weeds and the result was supported by the findings of Sreelakshmi et al., (2016).

A negative linear relationship between weed dry weight at 30 DAS, 45 DAS and 60 DAS with grain yield was observed (R^2=0.5353, 0.5188, 0.365 respectively, for weed dry weight at 30 DAS and grain yield, weed dry weight at 45 DAS and grain yield, and weed dry weight at 60 DAS and grain yield (Figure 1;a, b, c).

Yield and yield attributes

The numbers of effective tillers m^{-2} were not influenced by tillage methods, but it differed significantly ($p<0.05$) due to weed management practices (Table 5). The number of effective tiller m^{-2} was significantly reduced in weedy check as compared with all other weed managed treatments. The effective tillers were comparitively lower in pendimethalin followed by 2,4-D application, and pendimethalin followed by penoxsulam sprayed. Effective tillers were highest in pendimethalin followed by hand weeding treatment, but it was statistically similar ($p<0.05$) to the weed management practices relalted treatments, except weedy check, pendimethalin fb 2,4-D, pendimethalin followed by bispyribac-Na, and pendimethalin followed by penoxsulam use. This findings matches well to the findings reported by Bhurer et al., (2013) as the authors had reported that this practice could reduced weed competition at critical crop growth stages, resulting in increased availability of nutrients, water and light to the crops and consequently results in high number of effective tillers per square meter.

Table 5. Yield attributes of DDSR treatments in relation to tillage methods and weed management practices at AFU, Rampur, Chitwan, 2016

Treatments	Effective Tiller m^{-2}	Grains per Panicle	TGW (g)	Sterility %	Grain yield (kg ha^{-1})
Tillage					
ZT	245	147^{b}	14.76	14.62	2898.28
CT	240	157^{a}	14.57	11.56	3305.96
SEm (±)	3.68	0.62	0.47	0.85	96.90
LSD (=0.05)	NS	3.77	NS	NS	NS
CV, %	2.6	0.7	5.5	11.3	5.4
WMP_1	176^{d}	116^{b}	15.01	24.26^{a}	1211.37^{d}
WMP_2	262^{ab}	153^{a}	15.29	10.38^{d}	3598.67^{ab}
WMP_3	282^{a}	153^{a}	13.70	10.57^{cd}	3742.00^{a}
WMP_4	211^{c}	149^{a}	15.37	14.71^{b}	3059.27^{c}
WMP_5	251^{b}	165^{a}	14.10	13.03^{bc}	3552.31^{ab}
WMP_6	261^{ab}	152^{a}	14.30	10.56^{cd}	2829.52^{c}
WMP_7	225^{c}	162^{a}	14.13	9.64^{d}	3185.21^{bc}
WMP_8	273^{ab}	166^{a}	15.45	11.54^{cd}	3638.61^{ab}
SEm (±)	7.84	7.65	0.83	0.83	154.00
LSD (=0.05)	22.71	22.17	NS	2.40	446.10
CV, %	7.9	12.30	13.70	15.50	12.20
Grand Mean	243	152	14.67	13.09	3102.12

Note: ZT, Zero Tillage; CT, Conventional Tillage; ns, Non-significant; TGW, Thousand Grain weight; Treatment means followed by common letter(s) are not significantly different among each other based on DMRT at 5% level of significance.

There was significant influence of tillage methods and weed management practices ($p<0.05$) on grains per panicle. Grains per panicle in conventional tillage were significantly higher. Grains per panicle in weedy check were significantly lower ($p<0.05$) than all other weed managed plots that were statistically similar ($p>0.05$) (Table 5).

The effect of tillage methods and weed management practices was non-significant ($p>0.05$) to the thousand grains weight (TGW). TGW in the case of zero tillage was higher, and among weed management practices, pendimethalin followed by tank mixture of bispyribac-Na and ethoxysulfuron spray produced the highest thousand grain weight.

Tillage methods were non-significant ($p>0.05$) to sterility and conventional tillage practices, resulting lower sterility. Sterility percentage was significantly influenced ($p<0.05$) by weed management practices. Weedy check resulted significantly highest ($p<0.05$) sterility cases than all other management practices. Pendimethalin followed by ethoxysulfuron spray resulted in lowest sterility which was statistically similar ($p>0.05$) with weed free, pendimethalin followed by penoxsulam spray; pendimethalin followed by hand weeding, and pendimethalin followed by tank mixture spray of bispyribac-Na and ethoxysulfuron (Table 5).

The grain yield of rice was significantly influenced ($p<0.05$) by weed management practices, but not by tillage method (Table 5). Between tillage methods, conventional method had produced higher grain yield. Higher grains per panicle, lower weed density and dry weight in conventional tillage were the factors leading to higher rice yield, and this result was supported by the research work of Rodriguez & Lal (1985). The grain yield of rice was significantly higher ($p<0.05$) in all weed management practices as compared to weedy check. The highest yield was obtained when pre-emergence application of pendimethalin was done followed by hand weeding, but it was statistically similar ($p>0.05$) to the grain yield of the treatments: use of pendimethalin followed by tank mix of bispyribac-Na + ethoxysulfuron spray; weed free and pendimethalin spray followed by bispyribac-Na use (Table 5). Lower weed density and weed dry weight in these treatments as compared to other weed management practices resulted higher rice grain yield (Table 3 & 4). Mahajan & Timsina, (2011) also reported about higher rice grain yield in pendimethalin use followed by hand weeding, and pendimethalin followed by bispyribac-Na treated treatments, and also stated that hand weeding was efficient than bispyribac-Na spray, mainly because of the selective control of annual grass by bispyribac-Na, and further stressed that bispyribac-Na was poor in controlling *Digitaria sanguinalis* which is one of the important weeds in DDSR case. Use of pendimethalin followed by tank mixture application of bispyribac-Na and ethoxysulfuron spray had, however, similar results ($p>0.05$), yet had comparatively produced higher grain yield than bispyribac-Na sprayed treatment (Table 5) perhaps due to increased spectrum of tank mixture over sole herbicide application in controlling weed (Hatzios & Penner, 1985). Khaliq et al. (2012), also reported that tank mixture application of post emergence herbicide reduced weed density and tank mixture application of Bispyribac-Na and ethoxysulfuron had the lowest weed density in rice.

A linear relationship between effective tillers per square meter with grain yield was observed ($R^2 = 0.3317$, $r = 0.576^{**}$) (Figure 1(d)).

CONCLUSION

The weed density and weed dry weight were almost similar for both tillage practices, except at earlier days where weed dry weight was influenced by tillage and was higher in zero tillage. Weed management practices influenced weed density and weed dry weight throughout the crop growing season. Application of pre-emergence herbicide followed by either hand weeding, or application of any one of post emergence herbicides reduced weed density and weed dry weight and improved rice grain yield . Application of popular pre-emergence herbicide, pendimethalin followed by manual weeding, or application of post-emergence herbicides bispyribac-Na, or tank mixture of bispyribac-Na and ethoxysulfuron could be the most effective protocol for controlling weeds in both conventional tillage and zero tillage of rice cultivation.

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REFERENCES

Baltazar, A. M., & De Datta, S. K. (1992). Weed management in rice. *Weed Abstract*. *41*, 495-508.

Bhurer, K. P., Yadav, D. N., Ladha, J. K., Thapa, R. B., & Pandey, K. R. (2013). Efficacy of various herbicides to control weeds in dry direct seeded rice (*Oryza sativa* L.). *Global Journal of Biotechnology, Agriculture and Health Science*, *2(4),* 205-212.

Devkota, K., Ranjit, J. D., Sherchan, D. P., Regmi, A., Akhtar, T., Humphreys, E., & Devkota, M (2014). Guidelines for Dry Seeded Rice (DSR): in the Terai and Mid Hills of Nepal. *CSISA and IFAD joint publication. International Rice Research Institute (IRRI) and the International Maize and Wheat Improvement Center (CIMMYT).* 40 p.

Estoninos, L. E., & Moody, K. (1988). Evaluation of herbicides for weed control in dry-seeded wetland rice (*Oryza sativa*). *Philippine Journal of Weed Science*, *28*, 31-38.

Feldman, S. R., Torres, C. A. P. S., & Lewis, P. (1997). The effect of different tillage systems on the composition of the seed bank. *Weed Research*, *37(2),* 71-76.

Gomez, K. A. & Gomez, A. A. (1984). *Statistical Procedures for Agricultural Research*. John Wiley & Sons.

Goswami, G., Singh, Y., & Kumar, S. (2017). Effect of agronomic practices and weed management practices on weed dry weight and weed control efficiency in direct seeded rice under rainfed condition of Eastern Uttar Pradesh, India. *International Journal of Current Microbiology and Applied Science*, *6(9),* 2132-2138.

Govindan, R., & Chinnusamy, C. (2014). Tillage, crop establishment and weed management in rice under conservation agriculture system. *Indian Journal of Weed Science*, *46*(*2)*, 117-122.

Hatzio, K. K., & Penner, D. (1985). Interactions of herbicides with other agrochemicals in higher plants. *Reviews of weed science*, *1*, 1-63.

Khaliq, A., Matloob, A., Mahmood, S., Abbas, R. N., & Khan, M. B. (2012). Seeding density and herbicide tank mixtures furnish better weed control and improve growth, yield and quality of direct seeded fine rice. *International Journal of Agriculture and Biology*, *14*, 499-508.

Kumar, A., Kumar, S., Dahiya, K., Kumar, S., & Kumar, M. (2015). Productivity and economics of direct seeded rice (*Oryza sativa* L.). *Journal of Applied and Natural Science*, *7(1),* 410-416.

Kumar, V., & Ladha, J. K. (2011). Direct seeding of rice: recent developments and future research needs. In *Advances in agronomy* (Vol. 111, pp. 297-413). Academic Press.

Mahajan, G., & Timsina, J. (2011). Effect of nitrogen rates and weed control methods on weeds abundance and yield of direct-seeded rice. *Archives of Agronomy and Soil Science*, *57*(*3*), 239-250.

Mahajan, G., Chauhan, B. S., & Johnson, D. E. (2009). Weed management in aerobic rice in Northwestern Indo-Gangetic Plains. *Journal of Crop Improvement*, *23*(*4*), 366-382.

MOALD (2017). Statistical information on Nepalese agriculture. Agribusiness Promotion and Statistics Division, Singh Darbar, Kathmandu.

Rao, A. N., Johnson, D. E., Sivaprasad, B., Ladha, J. K., & Mortimer, A. M. (2007). Weed management in directseeded rice. *Advances in Agronomy*, *93*, 153-255.

Rodriguez, M. S., & Lal, R. (1985). Growth and yield of paddy rice as affected by tillage and nitrogen levels. *Soil and Tillage Research*, *6*(*2*), 163-178.

Sreelakshmi, K., Balasubramanian, R., Babu, R., & Balakrishnan, K. (2016). Herbicide combinations for weed management in transplanted rice. *Indian Journal of Weed Science*, *48*(*1*), 60-63.