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Effective Weed Management in Dry Direct Seeded Rice for Sustainable Productivity

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Abstract

Direct seeded rice (DSR) is the only viable option for rice production under shrinking water resources however, to harvest good crop yield effective weed management is essential. In the field area of Rice Research Institute, Kala Shah Kaku, Pakistan a field experiment was conducted during the growing season 2013 to identify appropriate herbicides to control weeds effectively in dry direct seeded rice. Randomized complete block design (RCBD) was used with three replications. The main weeds identified with dry direct seeded rice included *Echinochloa colona*, *Echinochloa cruss-galli*, *Diplachne fusca*, *Cyperus iria*, *Cyperus difformis*, *Scirpus meritimus*, *Cyperus rotundus*, *Marsilia minuta* and *Conyza stricta*. Twelve pre and post emergence herbicidal treatments were tested and compared with weedy check. A pre-emergence herbicide was applied just after seeding and the post-emergence herbicides were applied at 21 and 40 days after seeding (DAS). Weed density m^{-2} was recorded at 20 and 45 days after seedling. The best weed control (94.8 - 98.1%) was achieved with two sprays (21 & 40 DAS) of post emergence herbicide (bispyribac sodium) followed by single application (21 DAS) of the same herbicide which gave weed control of 77.5 to 82.3 %. orthosulfamuron, penoxsulam and ethoxysulfuron as post emergence herbicides were found more effective against broad leaf weeds and sedges than grasses. As regards paddy yield, it was found to be maximum (3.97 - 4.14 t ha^{-1}) with the twice application of bispyrabic sodium (Clover 20% SC or Nominee 20% SC) whereas, the lowest paddy yield was recorded in case of weedy check (0.41 t ha^{-1}). Number of productive tillers m^{-2}, number of filled grains $panicle^{-1}$ and 1000-grain weight (g) were also higher in the plots having twice application of bispyribac sodium than other herbicidal treatments and weedy check. Thus, in the fields having mixed weed flora (grasses, broad leaf weeds and sedges) twice application of bispyribac sodium applied at 21 and 40 days after sowing at the rate of 250 ml ha^{-1} or 200 g ha^{-1} gave good results. However, in plots where only broad leaf weeds and sedges predominate, ethoxysulfuron at the rate of 50 g ha^{-1} or orthosulfamuron at the rate of 120 g ha^{-1} were found to be more appropriate suitable herbicides to be used.

1 Introduction

The growth of world's population is expected to exceed upto 8.5 billion by the year 2020 (Diczfalusy, 2012) and subsequently, this will increase requirement of rice and other food production. This could be satisfied, either by increasing areas of crops or by achieving higher crop yields. The first option may not be feasible due to various economic and environmental reasons. In Asia during the past decade, rice area in

most of the countries has remained static or even declined. Therefore, production should be increased by increasing the yield per unit area (Maan *et al.,* 2007). In Pakistan area under rice crop is 2.72 million hectares producing annually 6.85 million tones of rice with an average yield of 2514 kg ha^{-1} (Anon., 2017). This average is considerably less than many other rice growing countries. There exists a good scope of increasing rice production as present yield level is quite low when compared the potential of our existing varieties. Less plant population per unit area is one of the major causes of low rice yield because transplanting is done manually in the extremely hot season and farm labour does not transplant required number of seedlings per acre despite vehement efforts of crop specialists, media publicity and farmers themselves. This issue has compelled the researchers to explore the new resource conservation production technologies by which required number of plants per unit area can be maintained.

Direct rice seeding or mechanized transplanting are the only alternate technologies where plant population can be increased but mechanized transplanting is very costly and difficult. The only way left is the adoption of direct seeded rice through which we can decrease the irrigation and labour requirements that will help us in minimizing production costs. In South Asian region, rice crop is widely grown through this technique of DSR in Bangladesh and India but it was found that suboptimal weed management practices leading to ineffective and poor weed control in DSR results in a 50-91% reduction in yield (Elliot *et al.*, 1984; Fujita, 1996; Gupta *et al.,* 2006; Hussain *et al.*, 2008). However, in farmers' field trails in Tevai of Uttaranchal, India, Pendimethalin within two sprayed within two days of sowing expressed good weed control along with higher grain yield in DSR (Singh *et al.,* 2005) that indicates that adoption of suitable weed management practices at appropriate time plays critical role to harvest good paddy yield of direct seeded rice (Akhtar *et al.,* 2010). However, cultural weed control methods demand intensive labour that is becoming scarce gradually. Therefore, chemical weed control by applying suitable herbicides at proper time and at appropriate dose is a viable solution for effective weed management. It necessitates the introduction of new herbicides with better performance for dry seeded rice (Gupta *et al.*, 2003). A couple of herbicides both for pre emergence and post emergence application have been explored that control weeds to a considerable extent in direct seeded rice (Moorthy and Mittra, 1992; Pellerin and Webster, 2004). The objective of this study was to upgrade the DSR technology coupled with effective weed management practices thus making it a cost effective, and farmer and eco-friendly technology.

2 Materials and Methods

A field study was conducted at Rice Research Institute, Kala Shah Kaku, Pakistan (31°45'35N 73°50'16E with altitude 205 m) during the year 2013 on clay loam soil with pH 8.19 to 8.29 and organic matter ranging from 0.27 to 0.39 % . A randomized complete block design (RCBD) was used replicated thrice with a plot size of 5m × 10 m (50 m^2). Six pre and post emergence herbicides as described in (Table-2) were tested and compared with weedy check (no weeding). Table-1 describes the physico-chemical traits of experimental whereas metreological data is presented in Fig.-1. Soil was prepared thoroughly after "rauni" (soaking irrigation) by giving two ploughings followed by two plankings. Seeding of dry seed of variety super basmati at the rate of 35 kg ha^{-1} was done on June 25, 2013 using rabi drill. First irrigation was applied just after seeding and subsequently field was irrigated repeatedly after every 5 days to keep the soil in saturation condition till the completion of tillering phase. Later on each irrigation was done at 75% soil moisture level and in total 18 irrigations were applied to the crop. Application of recommended fertilizer was made at the rate of 133-85-62 kg NPK ha^{-1} in the form of Urea, DAP and SOP, respectively. All P and K while one third of N fertilizer was added to the soil before seeding during seed bed preparation. The remaining N fertilizer was applied in two equal splits i.e. at 35 days after seeding and at panicle initiation stage. Pre-emergence weedicide application was made just after seeding while post-emergence herbicides application was done at 21 and 40 days after seeding.

Table-1. Soil physico-chemical properties of experimental site

Parameter	Soil Depth (inches) 0-6	6-12
EC (dsm^{-1})	1.31	0.94
Soil pH	8.19	8.29
Organic matter (%)	0.39	0.27
Nitrogen (%)	0.48	0.31
Available phosphorus (ppm)	5.1	4.9
Available potash (ppm)	91	78
Saturation (%)	44	38
Texture	Clay loam	Clay loam
SAR (m mol L^{-1})	7.01	7.25

Table-2: Different herbicidal treatments for effective weed control in direct seeded rice

	Trade Name	Common Name	Time of application/ Spray (DAS)	Dose ha^{-1}
T_1	Stomp 330 E	pendimethalin	0	2500 ml
T_2	Nominee 20 % SC	bispyribac sodium	21	250 ml
T_3	Nominee 20 % SC	bispyribac sodium	21 and 40	250 ml
T_4	Clover 20 % SC	bispyribac sodium	21 DAS	200 g
T_5	Clover 20 % SC	bispyribac sodium	21 and 40	200 g
T_6	Ryzelan 240 SC	penoxsulam	21 and 40	125 ml
T_7	Sunstar Gold 60 % WG	ethoxysulfuron	21 and 40	50 g
T_8	Kelion 50 WG	orthosulfamuron	21 and 40	120 g
T_9	Stomp 330 E + Nominee 20 % SC	pendimethalin and bispyribac sodium	0 and 21	2500 ml + 200 ml
T_{10}	Stomp 330 E + Ryzelan 240 SC	pendimethalin and penoxsulam	0 and 21	2500 ml + 125 ml
T_{11}	Stomp 330 E + Sunstar Gold 60 % WG	pendimethalin and ethoxysulfuron	0 and 21	2500 ml + 50 g
T_{12}	Stomp 330 E + Kelion 50 WG	pendimethalin and orthosulfamuron	0 and 21	2500 ml + 120 g

The data on weed density m^{-2} before and after herbicide application was recorded. The crop was harvested on November 12, 2013 and the data on number of productive tillers m^{-2}, number of filled grains per panicle, 1000-grain weight (g) and paddy yield (t ha^{-1}) was recorded. The data were subjected to ANOVA technique by applying M-Stat C software and Fisher's protected LSD test was used to separate the means (Steel and Torrie, 1997).

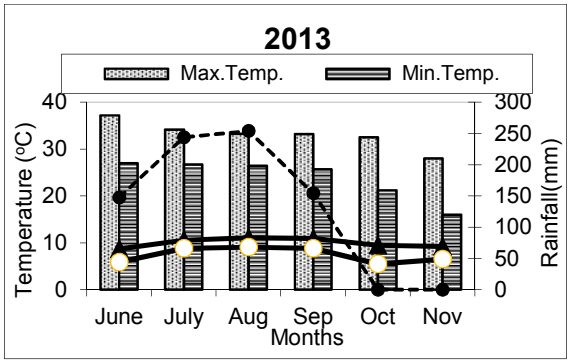

Fig.1. Metreological data of experimental site during the growing season 2013

3 Results and Discussion

The weeds infesting the experimental area are given in Table-3.

3.1 Weed density

The weed species infesting the experimental field are given in Table-3. The results indicated that the herbicide treatments significantly ($P<0.05$) affected the weed density (Table-4). Thus, minimum post treatment weed density (6.4 m^{-2}) at 45 days after sowing was achieved with two applications of nominee 20% SC; first at 21 days after sowing and the 2nd 40 days after sowing. It was followed by the twice application of Clover 20% SC and these two treatments remained statistically at par with each other. Whereas, the highest number of weeds (251.2 m^{-2}) was observed in the weedy check (control) plots. It was also observed that Stomp 330E alone as a pre-emergence herbicide was not much effective to control early flush of weeds while in combination with bispyribac sodium, penoxsulam and orthosulfamuron it gave better weed control than the sole application of these herbicides. Similar results were reported by Hess and Rose (1995) and Nagappa *et al.* (2002).

Table-3. List of weeds found in dry direct seeded rice crop

Botanical name	English name	Common name
	Broad leaf weeds	
Sphenoclea zeylancia	Goose weed	Mirchi booti
Marsilea minuta	Water clover	Chaupatti
Conyza stricta	Bitter weed	Daryai booti
	Sedges	
Cyperus rotundus	Purple nut sedge	Morke
Cyperus defformis	Umbrella plant	Ghooin
Scirpus meritimus	Bulrush	Deela
Cyperus iria	Flat sedge	Bhoin
Fimbristylis dichotoma	Globe frigerush	Chooti bhoin
	Grasses	
Paspalum distichum	Water grass	Naru
Echinochloa crus-galli	Barnyard grass	Dhiddon
Echinochloa colona	Jungle rice	Swanki
Diplachne fusca	Sprangle top	Kallar grass
Cynodon dactylon	Creeper grass	Khabbal
Dactyloctenium aegyptium	Egyptian finger grass	Madhana

In terms of percent weed control twice application of Nominee 20%SC and Clover 20%SC herbicides containing bispyribac sodium as gamma isomer gave the best weed control over all types of weeds which was 98.1 % and 94.8%, respectively and these were found statistically at par with each other, whereas, single application of these herbicides was not as effective as twice application (Table-5). Ryzelan (penoxsulam), Kelion (orthosulfamuron) and Sunstar Gold (ethoxysulfuron) as post-emergence treatments were found more effective against broadleaf weeds and sedges than in case of grasses. The results are in conformity with Saini and Angiras (2002) and Maan *et al.* (2007) finding, who reported that application of ethoxysulfuron gave good weed control for broad leave weeds and sedges in rice crop.

3.2 Number of productive tillers per m2

The comparison of mean values regarding number of productive tillers per m^{-2} (Table-6) indicated that productive tillers were maximum in the plots treated with post-emergence herbicide Nominee
(418.2 m^{-2}) followed by Clover (390.6 m^{-2}) and these two treatments were statistically at par with each other. The other herbicide treatments gave comparatively lower number of productive tillers. The lowest numbers of productive tillers m^{-2} were counted in weedy check plots. The results are in line with the findings of Singh *et al.* (2006) who reported that yield and yield components decreased in case of herbicide untreated plots in rice crop.

3.3 Number of filled grains per panicle

The effect of herbicide treatments on number of filled grains $panicle^{-1}$ were found to be highly significant ($P<0.01$). Thus, the highest number of filled grains $panicle^{-1}$ (116.3) was recorded from the plots sprayed with Nominee 20% SC on 21 and 40 DAS (T_3) and it was followed by T_5 (Clover 20% SC sprayed at 21 & 40 DAS) which produced 107.1 filled grains $panicle^{-1}$ and these treatments were statistically at par with each other (Table-6). The lowest number of filled grains per panicle were found in case of weedy check plots (43.6). The results are in conformity with that of Nagappa *et al.* (2002) who reported higher number of filled grains $panicle^{-1}$ in case of herbicides treated plots than untreated plots.

1000-grain weight (g)

The results indicated that herbicide treatments had a significant ($P<0.05$) effect on grain weight. The highest 1000-grain weight of 21.92 g was recorded with the treatment T_3 where Nominee was applied twice (21 & 40 DAS) and it was followed by Clover treated plots (T_5) which gave 21.73 g weight of 1000 grains and the differences between these two treatments were found to be non-significant statistically (Table-6). The data showed that sole application of Nominee or Clover (21 & 40 DAS) proved to be superior to the combination of Nominee with Stomp. Whilst the lowest 1000-grain weight of 20.11 g was recorded in case of weedy check.

Table-4. Weed density m^{-2} at 20 and 45 days after sowing as influenced by different herbicidal treatments

Herbicidal Treatments		Pre-treatment weed density (20 DAS)				Post-treatment weed density 45 DAS			
		Grasses	Sedges	Broad Leaves	Total	Grasses	Sedges	Broad Leaves	Total
T_1	Stomp 330 E (Spray at 0 DAS)	98.0 a	81.3 c	61.3 e	240.6 a	87.7 a	78.0 a	54.7 b	220.3 b
T_2	Nominee 20 % SC (Spray at 21 DAS)	77.3 d	88.4 b	90.2 b	255.9 a	19.8 d	17.4 b	9.7 d	36.9 f
T_3	Nominee 20 % SC (Spray at 21 & 40 DAS)	88.7 b	78.7 c	53.7 c	221.1 b	3.4 e	1.3 d	1.7 c	6.4 h
T_4	Clover 20 % SC (Spray at 21 DAS)	80.6 c	81.1 c	77.4 c	239.1 a	23.4 d	19.3 b	11.2 d	43.9 f
T_5	Clover 20 % SC (Spray at 21 & 40 DAS)	75.0 d	82.0 c	72.7 d	229.7 b	5.3 e	3.7 e	2.8 e	9.8 h
T_6	Ryzelan 240 SC (Spray at 21 & 40 DAS)	68.7 d	105.7 a	39.3 b	213.7 bc	36.0 c	25.7 b	19.1 c	100.8 d
T_7	Sunstar Gold 60 % WG (Spray at 21 & 40 DAS)	100.7 a	75.3 d	54.0 e	230.0 b	80.7 a	16.3 b	27.4 c	135.3 c
T_8	Kelion 50 WG (Spray at 21 & 40 DAS)	80.0 c	93.3 b	97.4 a	270.7 a	32.0 c	24.7 b	47.0 b	103.7 d
T_9	Stomp 330 E + Nominee 20%SC (Spray at 0 + 21 DAS)	74.7 d	53.0 b	85.7 b	210.4 c	10.0 e	13.0 e	2.0 c	25.1 f
T_{10}	Stomp 330 E + Ryzelan 240 SC (Spray at 0 & 21 DAS)	84.2 c	80.1 c	71.3 d	235.6 a	31.6 c	26.3 b	19.7 c	57.6 f
T_{11}	Stomp 330 E + Sunstar Gold 60 % WG (Spray at 0 & 21 DAS)	71.4 d	82.3 c	79.4 c	232.8 b	57.0 b	16.9 b	17.3 c	96.7 d
T_{12}	Stomp 330 E + Kelion 50 WG (Spray at 0 & 21 DAS)	81.1 c	70.3 e	80.4 c	231.8 b	34.7 c	18.6 b	17.1 c	70.4 e
T_{13}	Weedy Check	82.7 c	79.0 c	78.1 c	239.8 a	85.8 a	82.0 a	83.4 a	251.2 a
	LSD	**5.29**	**8.17**	**6.24**	**34.72**	**9.68**	**11.31**	**10.51**	**12.23**

LSD: Least Significant Difference

Means followed by different letters in the respective columns are significantly different by Fisher's Protected LSD test at $p \leq 0.05$.

Paddy yield (t ha^{-1})

All herbicide treatments except sole application of Stomp 330E gave significantly ($P<0.05$) higher paddy yield than weedy check (Table-6). Thus, the maximum paddy yield (4.14 t ha^{-1}) was achieved with the treatment T_3 where Nominee 20%SC was applied twice (21 & 40 DAS) and it was followed by T_5 (Clover 20%SC sprayed on 21 & 40 DAS) which produced 3.97 t ha^{-1} paddy however, these two treatments remained statistically at par with each other. Amongst the combined application of different herbicides, T_9 (Stomp 330E + Nominee 20%SC sprayed at 0 and 20 DAS) expressed significantly ($P<0.05$) higher paddy yield than all other herbicide combinations by producing 3.78 t ha^{-1} paddy. Whereas, the lowest paddy yield of 0.41 t ha^{-1} was recorded with treatment of weedy check that remained statistically at par with that of T_1, where pre-emergence application of Stomp 330E was made. Our findings get support from the earlier work of other researchers who reported that effective weed control with herbicide application improved grain yield in transplanted rice (Bhowmick and Ghosh, 2002) as well as in direct wet-seeded rice (Saini and Angiras, 2002; Ashraf *et al.*, 2006). Increased grain yield as a result of effective weed control through herbicides was also reported by Ishaya *et al*. (2007).

Table-5. Percent weed control of pre and post-emergence herbicides

	Herbicidal Treatments	Percent Weed Control			
		Grasses	Sedges	Broad leaves	Average
T_1	Stomp 330 E (Spray at 0 DAS)	10.5 g	4.0 d	10.7 e	8.4
T_2	Nominee 20 % SC (Spray at 21 DAS)	74.3 c	80.3 b	89.2 b	82.3 b
T_3	Nominee 20 % SC (Spray at 21 & 40 DAS)	96.4 a	98.3 a	99.6 a	98.1 a
T_4	Clover 20 % SC (Spray at 21 DAS)	70.9 c	76.2 b	85.5 b	77.5 c
T_5	Clover 20 % SC (Spray at 21 & 40 DAS)	92.9 a	95.4 a	96.1 a	94.8 a
T_6	Ryzelan 240 SC (Spray at 21 & 40 DAS)	47.6 e	75.6 b	51.3 d	58.2 d
T_7	Sunstar Gold 60 % WG (Spray at 21 & 40 DAS)	19.8 f	78.3 b	49.2 d	49.1 e
T_8	Kelion 50 WG (Spray at 21 & 40 DAS)	60.0 d	73.5 b	51.7 d	61.7 d
T_9	Stomp 330 E + Nominee 20%SC (Spray at 0 + 21 DAS)	86.6 b	75.4 b	97.6 a	86.5 b
T_{10}	Stomp 330 E + Ryzelan 240 SC (Spray at 0 & 21 DAS)	62.4cd	67.2 c	72.3 c	67.3 d
T_{11}	Stomp 330 E + Sunstar Gold 60 % WG (Spray at 0 & 21 DAS)	20.2 b	79.3 b	78.6 c	59.4 d
T_{12}	Stomp 330 E + Kelion 50 WG (Spray at 0 & 21 DAS)	57.2 d	73.5 b	78.7 c	69.8 cd
T_{13}	Weedy Check	-	-	-	-
	LSD	**6.94**	**8.71**	**8.13**	**7.52**

Means followed by different letters in the respective columns are significantly different by Fisher's Protected LSD test at $p \leq 0.05$.

Table 6: Effect of herbicide application on paddy yield and yield components

	Herbicidal Treatments	No. of tillers per m^2	No. of filled grains per panicle	1000 grain weight (g)	Paddy yield (t/ha)
T_1	Stomp 330 E (Spray at 0 DAS)	57.0 e	46.7 d	20.41 b	0.62 e
T_2	Nominee 20 % SC (Spray at 21 DAS)	406.7 a	105.7 a	21.09 a	3.57 b
T_3	Nominee 20 % SC (Spray at 21 & 40 DAS)	418.2 a	116.3 a	21.92 a	4.14 a
T_4	Clover 20 % SC (Spray at 21 DAS)	373.4 a	103.4 a	20.91 a	3.36 c
T_5	Clover 20 % SC (Spray at 21 & 40 DAS)	390.6 a	107.1 a	21.73 a	3.97 a
T_6	Ryzelan 240 SC (Spray at 21 & 40 DAS)	231.2 bc	76.3 bc	20.62 b	1.76 d
T_7	Sunstar Gold 60 % WG (Spray at 21 & 40 DAS)	187.1 d	68.2 c	20.21 b	1.42 de
T_8	Kelion 50 WG (Spray at 21 & 40 DAS)	214.3 c	74.1 bc	20.61 b	1.66 d
T_9	Stomp 330 E + Nominee 20%SC (Spray at 0 + 21 DAS)	412.3 a	107.3 a	20.97 a	3.78 b
T_{10}	Stomp 330 E + Ryzelan 240 SC (Spray at 0 & 21 DAS)	266.2 b	84.6 b	20.49 b	1.83 d
T_{11}	Stomp 330 E + Sunstar Gold 60 % WG (Spray at 0 & 21 DAS)	234.8 bc	76.7 bc	20.31 b	1.71 d
T_{12}	Stomp 330 E + Kelion 50 WG (Spray at 0 & 21 DAS)	267.3 b	82.3 bc	20.67 b	2.11 d
T_{13}	Weedy Check	46.0 e	43.6 d	20.11 b	0.41 e
	LSD	**49.65**	**17.79**	**1.49**	**0.4167**

Means followed by different letters in the respective columns are significantly different by Fisher's Protected LSD test at $p \leq 0.05$.

4 Conclusion

It can be concluded from the study that in dry direct seeded rice an effective control of weeds (i.e. grasses, broad leaf weeds and sedges) and ultimately the higher paddy yield could be achieved with twice application of bispyribac sodium applied at 21 and 40 days after sowing at the rate of 250 ml ha^{-1} or 200 g ha^{-1}. However, in fields where broad leaf weeds and sedges predominate, ethoxysulfuron at the rate of 50 g ha^{-1} or orthosulfamuron at the rate of 120 g ha^{-1} are more appropriate herbicides to be used. Selection and timely application of suitable herbicides based on prevailing weed flora would enable the rice growers to harvest better paddy yield at comparatively lower cost.

References

1. Akhtar,M., I.Ali and M.U.Saleem. 2010. Harmful insects, diseases, weeds of rice and their control. Rice Research Institute Publication. p. 14-20.

2. Anonymous. 2018. Economic Survey of Pakistan. Govt. of Pakistan. Finance Division Economic Advisory Wing, Islamabad. p. 21.

3. Ashraf, M.M., T.H. Awan, Z. Manzoor, M. Ahmad and M.E. Safdar.2006. Screening of herbicides for weed management in transplanted rice. Journal of Animal and Plant Sciences 16(1-2): 92-95.

4. Bhowmick, M.K. and R.K. Ghosh. 2002. Relative efficacy of herbicides against weed incidence in summer rice. Advances in Plant Sciences 15 (2): 499-503.

5. Diczfalusy, E. 2012. Growing rapidly and ageing rapidly, or the tyranny of numbers. First Consensus Meeting on Menopause in the East Asian Region. Karolinska Institute, Stockholm, Sweden <http://www.gfmer.ch/Books/bookmp/11.htm> (accessed on June 11, 2014).

6. Elliot, P.C., D.C. Navarez, D.B. Estario and K. Moody. 1984. Determining suitable weed control practices for dry – seeded rice. Philippine Journal of Weed Science 11:70-82.

7. Fujita, K. 1996. Effect of several herbicides application on growth of shoots and roots of rice seedlings at the nursery stage. Weed Research 41: 44-54.

8. Gupta, R.K., J.K. Ladha, S. Singh, R.J. Singh, M.L. Jat, Y. Saharawat, V.P. Singh, S.S. Singh, G. Sah, et al. 2006. Production technology for direct seeded rice. Rice Wheat Consortium Technical Bulletin 8. New Delhi, India. Rice Wheat Consortium for the Indo-Gagetic Plains. p. 16.

9. Gupta, R.K., R.K. Naresh, P.R. Hobbs, Z. Jiaguo and J.K. Ladha. 2003. Sustainability of post-green revolution agriculture: the rice-wheat cropping system of the Indo-Gangetic Plains and China. In: Ladha LK et al. (eds). Improving the Productivity and Sustainability of Rice-Wheat Systems: Issues and Impact. ASA Special Publication 65, ASA, Madison, WI, USA. 1:1-25.

10. Hussain, S., M. Ramzan, M. Akhter and M. Asalam. 2008. Weed management in direct seeded rice. Journal of Animal and Plant Sciences 18: (2-3): 86-88.

11. Hess, M. and E. Rose. 1995. HOE 095404: a new herbicide for broadleaf weed and sedge control in rice. In Brighton Crop Protection Conference Weeds, vol. 2, p. 763-768. Brit. Crop protection Council.

12. Ishaya, D.B., S.A. Dadari and J.A.Y. Shebayan. 2007. Evaluation of herbicides for weed control in three varieties of upland rice (oryza sativa L.) in the Nigerian Savannah. Crop Protection 26(10):1490-1495.

13. Maan, R.A, S. Ahmad, G. Hassan and M.S. Baloch. 2007. Weed management in direct seeded rice crop. Pakistan Journal of Weed Science Research 13(3-4): 219-226.

14. Moorthy, B.T.S. and B.N. Mittra. 1992. Reduction of herbicide phytotoxicity on upland rice by use of protectants. International Journal of Pest Management 38(3): 295-297.

15. Nagappa, N., D. Naresh and D.P. Biradar. 2002. Efficiency of different herbicides to control weeds and its impact on yield in direct seeded rice of Tunga Bhadra project area. Karnataka Journal of Agricultural Sciences 15:359-361.

16. Pellerin, K.J. and E.P. Webster. 2004. Imazethapyr at different rates and timings in drill and water seeded imidazolinone-tolerant rice. Weed Technology 18:23–227.

17. Saini, J.P. and N.N. Angrias. 2002. Evaluation of ethoxysulfuron against broad-leaved weeds and sedges in direct seeded puddled rice. Indian Journal of Weed Science 34:36–38.

18. Singh, S., L. Bhushan, J.K. Ladha, R.K. Gupta, A.N. Rao and B. Sivaprasad. 2006. Weed management in dry-seeded rice (Oryza sativa) cultivated in the furrow-irrigated raised-bed planting system. Crop Protection 25(5):487-495.

19. Singh, V.P., G. Singh, S.P. Singh, A. Kumar, Y. Singh, D.E. Johnson and M. Mortimer. 2005. Effect of rice wheat establishment methods and weed management in irrigated rice-wheat production system. In Workshop on Direct Seeded Rice in the Rice-wheat System of the IGP, 1-2 Feb.2005, G.B. Pant University of Agric & Technol., Uttaranchal, India, p. 12.

20. Steel, R.G.D. and J.H. Torrie. 1997. Principles and procedures of statistics. Mc Graw Hill Book Co. Inc. Singapore, p. 172-177.