The Pharma Innovation Journal 2022; 11(10): 1727-1730

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(10): 1727-1730

www.thepharmajournal.com
Received: 22-08-2022
Accepted: 26-09-2022

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Evaluation of different weed management approaches in managing weeds in direct seeded rice (*Oryza sativa* L.)

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Abstract
A field experiment was conducted during *Kharif* 2020 and 2021 at Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh to evaluate efficacy of different weed management practices in managing weeds in direct-seeded rice (*Oryza sativa* L.). The weed species *Echinochloa colona*, *Cyperus iria* and *Alternanthera sessilis* were found dominant among the grasses, sedges and broad leave weeds during both years. Among the integrated weed management practices, the lowest weed biomass and maximum weed control efficiency, were computed in the OD *fb* MW (20 DAS) *fb* HW (40 DAS) (T_4) treatment at 60 DAS. The maximum growth parameters value were recorded under the WF (20, 40 and 60 DAS) (T_{13}) treatment at 60 DAS. No significant difference in SPAD value was observed at 60 DAS. The highest grain yield was recorded under the WF (20, 40 and 60 DAS) (T_{13}) treatment, which was found at par with the OD *fb* HW (20 and 40 DAS) (T_3), OD *fb* MW (20 DAS) *fb* HW (40 DAS) (T_4), MW+IHW (15 and 35 DAS) (T_{12}) and OD *fb* BS (20 DAS) (T_5) treatments. The maximum and minimum B:C ratio were computed under the OD *fb* BS (20 DAS) (T_5) and weedy check (T_{14}) treatments, respectively.

Keywords: Direct seeded rice, integrated weed management, motorised weeder

Introduction
Rice (*Oryza sativa* L.) is a primary food crop grown widely over 161 million hectares in more than hundred countries of the world (FAOSTAT, 2020) [4] with an annual production of about 678.7 million tonnes of rice (Anon., 2019) [3]. It is the staple food for more than half of the world's population (IRRI, 2009) [2] and almost 90% of the world's rice is produced and consumed in Asia to provide up to three-fourths of the total calories required by 520 million Asians (Priya *et al*., 2019) [9]. India is the world's largest producer and accounting for 22% of the world's rice production after China. Again it accounted for over 1.8 trillion Indian rupees in the Indian economy in fiscal year 2018 (Anon., 2020) [4, 5]. Joshi *et al.* (2013) [7] noted the edge of direct seeded rice (DSR) over transplanted rice as it is a low-cost establishment technology and provides an opportunity to improve water and environmental sustainability. Again, it does away with the need for, nursery preparation, uprooting of seedlings and transplanting (Adnyana *et al*., 2019) [1] leading to lower water and labour requirement than manually transplanted rice. Direct seeded rice systems are subjected to much higher weed pressure than puddled transplanted rice systems (Rao *et al*., 2008) [13], in which weeds are suppressed by standing water and transplanted rice seedlings, which provide "head start" over germinating weed seedlings. Weeds in DSR compete for moisture, nutrients, light and space and reduce the grain yield by 75 to 85% (Rao *et al.* 2007; Dhanapal *et al.* 2018) [12, 6]. Thus weed management would continue to play a key role to meet the growing food demands of increasing population. As the weed problems are multi-pronged, a holistic multi-disciplinary integrated approach would be imperative. In this context, integrated weed management (IWM) may provide a more sustainable approach to rice production (Rao, 2011) [11]. For season-long and broad-spectrum sustainable weed management, an integration of different herbicides and weed control measures is needed as part of an IWM strategy.

Material and Methods
The field experiment was conducted during *Kharif* 2020 and 2021 at Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh. The soil pH was 6.7 (neutral in reaction). It was low in available nitrogen, medium in phosphorus and high in potassium. Fourteen weed management practices *viz.*

oxadiargyl 80 g/ha pre emergence (PE) followed by (*fb*) hand weeding (HW) at 25 DAS (T_1) [OD *fb* HW (25 DAS)], oxadiargyl 80 g/ha PE *fb* motorised weeding (MW) at 20 DAS (T_2) [OD *fb* MW (20 DAS)], oxadiargyl 80 g/ha PE *fb* HW at 20 & 40 DAS (T_3) [OD *fb* HW (20 and 40 DAS)], oxadiargyl 80 g/ha PE *fb* MW at 20 DAS *fb* HW at 40 DAS (T_4) [OD *fb* MW (20 DAS) *fb* HW (40 DAS)], oxadiargyl 80 g/ha PE *fb* bispyribac sodium @ 25 g/ha at 20 DAS (T_5) [OD *fb* BS (20 DAS)], oxadiargyl 80 g/ha PE *fb* premix penoxsulam + cyhalofop-butyl 135 g/ha at 20 DAS (T_6) [OD *fb* PXS+CFB (20 DAS)], oxadiargyl 80 g/ha PE *fb* fenoxaprop-p-ethyl 60 g/ha+ ethoxysulfuron 15 g/ha at 20 DAS (T_7) [OD *fb* FPE+EXS (20 DAS)], oxadiargyl 80 g/ha PE *fb* premix florpyrauxifen benzyl + cyhalofop butyl at 20 DAS (T_8) [OD *fb* FPB+CFB (20 DAS)], trifamone+ ethoxysulfuron 67.5 g/ha PE *fb* one spot HW at 40 DAS (T_9) [TFM+EXS (15 DAS) *fb* SHW (40 DAS)], premix florpyrauxifen-benzyl + cyhalofop butyl at 15 DAS + spot HW at 40 DAS (T_{10}) [FPB+CFB (15 DAS) *fb* SHW (40 DAS)], motorised weeder (double row type) at 15 and 35 DAS (T_{11}) [MW (15 and 35 DAS)], motorized weeder (double row type) + intrarow HW at 15 and 35 DAS (T_{12}) [MW+IHW (15 and 35 DAS)], weed free (20, 40 and 60 DAS) (T_{13}) and weedy check (T_{14}) were taken during both years. These eleven treatments were laid out in randomized block design with three replications. Pre-germinated seeds of medium duration rice variety 'Indira Rajeshwari (IGKV R 1)' were line sown through multi crop planter fitted with inclined plate seed metering device on levelled field on 03rd July and 26th June of 2020 and 2021, respectively, with a seed rate of 40 kg/ha. The crop was fertilized with 100:60:40 @ $N:P_2O_5:K_2O$ kg/ha, respectively during both the years. The whole amount of P and K were applied as basal dressing during final land preparation. The nitrogen fertilizer was applied in three splits, 50% at basal, 25% at tillering stage (30 DAS) and 25% at panicle initiation (60 DAS).

The study area receives average annual rainfall of 783 mm in 2020 and 855 mm in 2021, with a temperature variation of 16.9 to 34.2 °C in 2020 and 22 to 34.4 °C in 2021. The herbicides were sprayed at 2-3 leaf stage of weeds by using knapsack sprayer mixed with water 500 litre/ha. All other agronomic and plant protection measures were adopted as per the recommended packages of IGKV, Raipur, Chhattisgarh, India. The data on weed biomass was recorded with the help of quadrate (0.5 x 0.5 m). The weed control efficiency was worked out on the basis of weed dry matter production. Data on grain yield was recorded. The B:C ratio was calculated from the net monetary return and cost of cultivation.

Result and Discussions

Weed flora composition

The various weed flora found under the experimental site are presented in Table 1. The major weed flora in the experimental field included *Cynodon dactylon, Dactyloctenium aegyptium, Digitaria sanguinalis, Ischaemum rugosum* and *Echinochloa colona* among grasses; *Cyperus difformis, Cyperus iria* and *Fimbristylis miliacea* among sedges, whereas among broad-leaf weeds, *Abutilon indicum, Alternanthera sessilis, Cassia tora, Commelina diffusa, Cyanotis axillaris, Eclipta alba, Ludwigia parviflora, Phyllanthus niruri and Physalis minima* were found.

The lowest total weed biomass was (Table 2) recorded in the WF (20, 40 and 60 DAS) (T_{13}) treatment followed by the OD *fb* HW (20 and 40 DAS) (T_3) treatment at 60 DAS. The pre *fb* post emergence herbicides application in OD *fb* BS (20 DAS) (T_5) treatment and integrated approach in OD *fb* HW (20 and 40 DAS) (T_3) treatment computed with 88 and 93% reduction in total weed biomass in comaparion to weedy check (T_{14}) treatment at 60 DAS. The maximum and minimum weed control efficiency were computed under the WF (20, 40 and 60 DAS) (T_{13}) and OD *fb* FPE+EXS (20 DAS) (T_7) treatments, respectively at 60 DAS. Among the integrated weed management practices, the maximum and minimum weed control efficiency, were computed in the OD *fb* MW (20 DAS) *fb* HW (40 DAS) (T_4) and FPB+C*FB* (15 DAS) *fb* SHW (40 DAS) (T_{10}) treatments, respectively. Saravanane (2020) [14] also reported higher weed control efficiency under integrated weed management practices.

Table 1: Weed flora composition of experimental field during *Kharif* 2020 and 2021

No.	Scientific Name	Common Name	Local Name	Family	Growth habit *	Relative density (%)	
A.	**Grasses**					**2020**	**2021**
1	*Echinochloa colona* (L.) Link	Jungle rice	Sawa	Poaceae	A M Rs	21.15	18.51
2	*Ischaemum rugosum* Salisb.	Wrinkle duck-beak	Badauri	Poaceae	A M Rs	1.89	1.77
3	*Dactyloctenium aegyptium* (L.) Willd	Crowfoot grass	Makada ghass	Poaceae	A M Rs	2.41	1.85
4	*Cynodon dactylon* (L.) Pers.	Bermuda grass	Dhoobi	Poaceae	P M Rs Rv	1.87	3.21
5	*Digitaria sanguinalis* L. (Scop.)	Large crabgrass	Ghud Doob	Poaceae	A M Rs Rv	2.25	1.86
B.	**Sedges**						
1	*Cyperus iria* L.	Ricefield flatsedge	Motha	Cyperaceae	A M Rs	11.84	15.61
2	*Cyperus difformis* L.	One arm sedge	Button motha	Cyperaceae	A M Rs	10.41	9.15
3	*Fimbristylis miliacea* (L.) Vahl.	Grass-like fimbry	Bandar puchhia	Cyperaceae	A M Rs	2.97	2.17
C.	**Broad-leaved weeds (BLW)**						
1	*Abutilon indicum*	Country mallow	Raksi	Malvaceae	A D Rs	2.87	1.94
2	*Alternanthera sessilis* (L.) DC.	Sessile joyweed	Resham kata	Amaranthaceae	P D Rs	16.48	14.19
3	*Cassia tora* (L.) Roxb.	Sickle pod	Charota	Fabaceae	A D Rs	2.44	1.78
4	*Commelina diffusa* L.	Climbing dayflower	Kawakeni	Commelinaceae	A D Rs Rv	2.87	2.36
5	*Cyanotis axillaris* L.	Spreading dayflower	Badhanula/ Pondi	Commelinaceae	A D Rs Rv	11.64	16.33
6	*Eclipta alba*	Country mallow	Bhrangraj	Malvaceae	A D Rs	2.23	2.44
7	*Ludwigia parviflora* Roxb.	Water primrose	Laung ghass	Onagraceae	A P D Rs	2.17	2.42
8	*Phyllanthus niruri* L.	Stonebreaker/ Gripeweed	Hajardana	Euphorbiaceae	A D Rs	2.39	2.27
9	*Physalis minima* L.	Sunberry/ Hogweed	Chirpoti	Solanaceae	A D Rs	2.14	2.13

Asterisk (*) details as**:** A: Annual; P: Perennial; M: Monocot; D: Dicot; Rs: Reproducing by seeds; Rv: Reproducing by vegetative means

Growth parameters

The growth parameters signifies the yield ability of a crop. The highest plant height was recorded under the WF (20, 40 and 60 DAS) (T_{13}) treatment, which was found at par with the OD *fb* HW (20 and 40 DAS) (T_3), OD *fb* MW (20 DAS) *fb* HW (40 DAS) (T_4), MW+IHW (15 and 35 DAS) (T_{12}) and OD *fb* BS (20 DAS) (T_5) treatments at 60 DAS (Table 2). The WF (20, 40 and 60 DAS) (T_{13}) treatment witnessed with the maximum dry matter accumulation, which was found statistically similar with the OD *fb* HW (20 and 40 DAS) (T_3) and OD *fb* MW (20 DAS) *fb* HW (40 DAS) (T_4) treatments. The chemical *fb* hand weeding and pre *fb* post emergence application of herbicides witnessed 43 and 34% higher crop dry matter accumulation than the weedy check treatment. It might be due to the effective weed control at early stage of crop weed competition. This ultimately resulted in reduced nutrient removal by weeds which might have enhanced the nutrient uptake by rice thereby enhanced the dry matter accumulation of rice. Ramachandiran and Balasubramanian (2012) [10] suggested that SPAD value reading is a measure of total chlorophyll content of leaves which indicates the greenness of leaves. The data revealed that no significant difference was noticed for the SPAD value at 60 DAS. The maximum and minimum value were noticed under the WF (20, 40 and 60 DAS) (T_{13}) and weedy check (T_{14}) treatments. It might be due to the higher level of nitrogen uptake resulting from higher weed control efficiency. Leaf area determines light interception and is an important parameter in determining plant productivity (Koester *et al*., 2014) [8]. The maximum leaf area was witnessed under the WF (20, 40 and 60 DAS) (T_{13}) treatment, which was found at par with the OD *fb* HW (20 and 40 DAS) (T_3), OD *fb* MW (20 DAS) *fb* HW (40 DAS) (T_4), MW+IHW (15 and 35 DAS) (T_{12}), OD *fb* HW (25 DAS) (T_1), OD *fb* BS (20 DAS) (T_5) and OD *fb* PXS+CFB (20 DAS) (T_6) treatments at 60 DAS.

Table 2: Growth parameters, weed biomass and weed control efficiency (WCE) as influenced by different weed management practices in direct seeded rice during *Kharif* 2020 and 2021 (pooled data of two years)

Treatments		Plant height (cm)	Dry matter accumulation (g m^{-2})	SPAD value	Leaf area ($\times 10^2$ cm^2 m^{-2})	Total weed biomass (g m^{-2})	WCE (%)
T1	OD *fb* HW (25 DAS)	83.4	287.8	38.34	487.9	2.16 (3.66)	88.00
T2	OD *fb* MW (20 DAS)	81.3	271.7	38.02	469.5	2.97 (7.83)	74.30
T3	OD *fb* HW (20 and 40 DAS)	84.8	312.8	39.52	502.9	1.73 (1.99)	93.50
T4	OD *fb* MW (20 DAS) *fb* HW (40 DAS)	84.6	307.7	39.15	494.6	1.86 (2.45)	92.00
T5	OD *fb* BS (20 DAS)	83.6	293.3	38.38	487.5	2.18 (3.74)	87.90
T6	OD *fb* PXS+CFB (20 DAS)	83.2	287.8	38.10	486.3	2.27 (4.14)	86.40
T7	OD *fb* FPE+EXS (20 DAS)	80.7	257.0	37.38	456.9	3.10 (8.63)	71.70
T8	OD *fb* FPB+CFB (20 DAS)	81.4	273.5	37.98	467.4	2.87 (7.22)	76.50
T9	TFM+EXS (15 DAS) *fb* SHW (40 DAS)	81.0	267.9	37.81	463.6	3.04 (8.26)	73.00
T10	FPB+CFB (15 DAS) *fb* SHW (40 DAS)	80.9	271.9	37.56	462.0	3.08 (8.49)	72.20
T11	MW (15 and 35 DAS)	81.1	296.3	37.70	464.4	2.91 (7.47)	75.40
T12	MW+IHW (15 and 35 DAS)	84.0	291.2	38.62	490.8	2.05 (3.20)	89.50
T13	WF (20, 40 and 60 DAS)	85.8	325.2	40.57	503.7	1.00 (0.00)	100.00
T14	WC	80.4	218.8	36.16	437.9	5.61 (30.50)	-
SEm±		0.83	9.35	0.64	8.14	0.04	-
LSD (P=0.05)		2.36	26.53	NS	23.11	0.11	-

Figures in parentheses are original values, data were transformed to values √(x+1) are in bold letters

Yield and Economics

The highest grain yield (Fig. 1) was recorded under the WF (20, 40 and 60 DAS) (T_{13}) treatment, which was found at par with the OD *fb* HW (20 and 40 DAS) (T_3), OD *fb* MW (20 DAS) *fb* HW (40 DAS) (T_4), MW+IHW (15 and 35 DAS) (T_{12}) and OD *fb* BS (20 DAS) (T_5) treatments. The weedy check (T_{14}) treatment computed with reduction in grain yield to an extent of 45% in comparison to pre *fb* post herbicides application in OD *fb* BS (20 DAS) (T_5) treatment, 48% in comparison to integrated approach in OD *fb* HW (20 and 40 DAS) (T_3) treatment, 49% in comparison to WF (20, 40 and 60 DAS) (T_{13}) treatment. The maximum and minimum B:C ratio (Fig. 1) were computed under the OD *fb* BS (20 DAS) (T_5) and weedy check (T_{14}) treatments, respectively. The maximum benefit cost ratio in OD *fb* BS (20 DAS) (T_5) treatment was mainly attributed to the higher grain yield and reduced cost of weed management due to effective control of all types of weeds (Yogananda *et al*., 2019) [15].

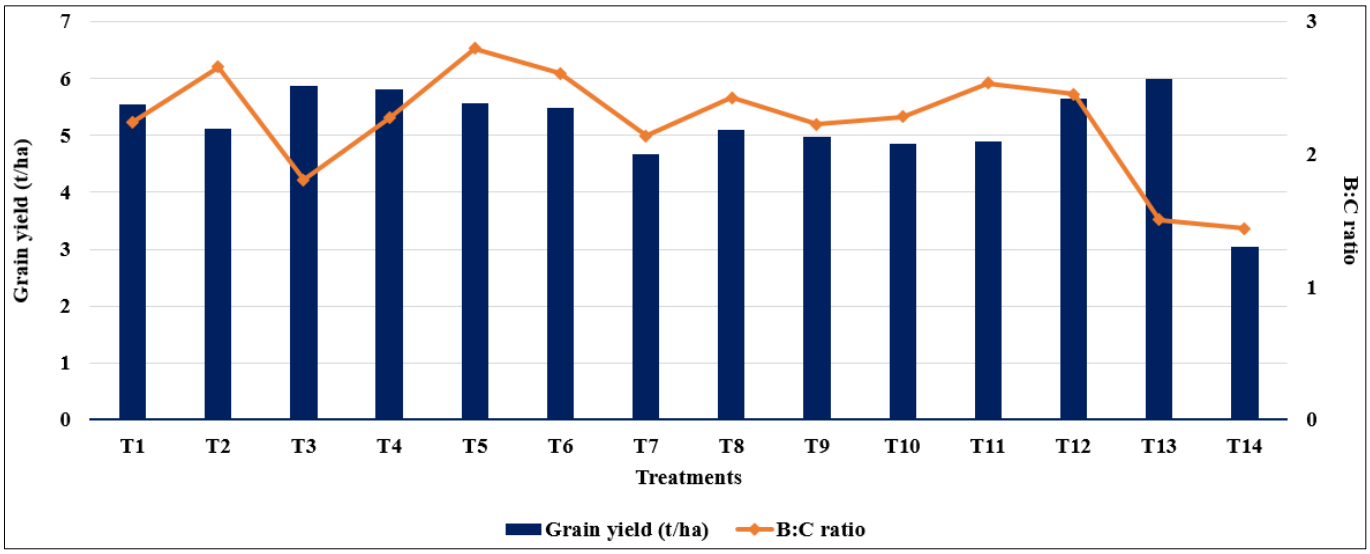

Fig 1: Grain yield and B:C ratio as influenced by different weed management practices in direct seeded rice during *Kharif* 2020 and 2021 (pooled data of two years)

Conclusion

The weed free treatment observed with the maximum growth parameters and yield. The integrated approach of chemical+manual weeding witnessed with the highest growth and yield among the integrated weed management practices. The pre *fb* post emergence application of herbicides computed with the highest B:C ratio. The chemical *fb* manual weeding approach may be promising in managing the weeds and ensure higher returns.

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