International Journal of Environment and Climate Change

Volume 12, Issue 12, Page 709-717, 2022; Article no.IJECC.94740
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Efficacy of New Herbicide Mixtures on Weed Control, Yield, and Economics in Transplanted Rice

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2022/v12i121506

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/94740

Received: 07/10/2022
Accepted: 13/12/2022
Published: 16/12/2022

Original Research Article

ABSTRACT

Aim: To evaluate the efficacy of new herbicide mixtures on the weed control and performance of transplanted rice.
Study Design: Randomized Complete Block Design.
Place and Duration of Study: All India Coordinated Research Project on Weed Management, PJTSAU, Hyderabad between August to December, 2021.
Methodology: The efficacy of herbicide mixtures either ready mix or as tank mixtures were evaluated for effective and broad spectrum weed control in transplanted rice during *kharif* season, 2021 at AICRP on Weed Management, PJTSAU, Rajendranagar, Hyderabad. The experiment was laid out in a randomized complete block design with nine treatments and three replications. The treatments included five ready mixes (RM) one tank mix combination of new herbicides tested against one single herbicide, weedy check and hand weeding twice at 20 and 40 DAT.
Results: The results of the study revealed that bispyribac sodium 10% SC 25 g ha^{-1}+ penoxsulam 1.02% (20 g ha^{-1}) (tank mix) as post-emergence (POE) *fb* hand weeding (HW) at 40 DAT or

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penoxsulam 0.97% (20 g ha^{-1}) + butachlor (38.8%) @ 820 g ha^{-1} (RM) as POE *fb* HW at 40 DAT or penoxsulam 1.02% (20g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) (RM) as POE *fb* HW at 40 DAT or bensulfuron methyl 0.6% (60 g ha^{-1}) + pretilachlor 6% (600g ha^{-1}) GR (RM) as pre-emergence (PE) *fb* HW at 40 DAT were equally effective to hand weeding twice at 20 and 40 DAT with respect to suppression of weeds at 60 DAT. The yield attributes like a number of tillers/m^2, panicles no, panicle length, grains $panicle^{-1}$ and test weight were found to be higher with penoxsulam 1.02% (20 g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) as POE *fb* HW at 40 DAT which also recorded higher grain yield, straw yield, gross returns, net returns and B-C ratio but it was found to be at par with other herbicide combinations.

Conclusion: It can be concluded that new herbicide mixtures either as ready mix or tank mix performed better than sole application or hand weeding alone.

Keywords: B-C ratio; herbicide mixtures; rice; weed dry weight; yield.

1. INTRODUCTION

"Among the cereals, rice is the most important and extensively grown in tropical and subtropical regions of the world and is a staple food for more than 60 percent of the world's population" [1]. "In India rice is grown over a 42.4 M ha area with a production of 104.4 M tons and productivity of 2.46 tons ha^{-1}" [2]. "Rice production needs to be increased by 50 % or more above the current production level to meet the rising food demand" [3]. "Weed infestation and interference is a serious problem in rice fields that significantly decreases the yield" [4]. "Weeds are ever - present and substantially decrease the quality and yield of crops" [5]. According to Mahbub and Bhuiyan [6], "the losses due to the infestation of the weeds are greater than the combined losses caused by insects, pests and diseases in rice. Weeds not only cause huge reductions in rice yields but also increase the cost of cultivation, reduce input efficiency, interfere with agricultural operations, impair the quality and act as alternate hosts for several insect pests and diseases". "Weeds compete for nutrients, space and sunlight and consume the available soil moisture with crop plants resulting in crop yield reduction. Weed management in rice production is a major constraint and is expensive. Since hand weeding and other weed control measures are laborious and time-consuming, chemicals are the obvious and cost-effective weed control practices" [7]. "Chemical weed control has become popular in India due to the scarcity of labor during peak growing seasons and lower weeding cost. Especially at the time of peak periods of labor crisis sometimes weeding becomes late causing drastic losses in grain yield" [8]. Nowadays the use of herbicides is gaining popularity in rice culture due to their rapid effects and less cost involvement compared to traditional methods. Quite a lot of pre and post-emergence herbicides such as butachlor, pretilachlor, oxadiazone, pyrazosulfuron ethyl, ethoxysulfuron, bispyribac sodium alone or supplemented with one-hand weeding have been found to be useful for weed control in transplanted rice. The use of a single herbicide might often lead to the control of only a particular group of weeds. So, to give farmers a wide choice of effective herbicides along with broad spectrum weed control, there is a need to evaluate the mixtures (either ready mix or tank mix) of herbicide molecules of newer chemistries with different modes of action. Hence, the present study was therefore planned to evaluate the efficacy of different herbicide mixtures for weed suppression and their impact on transplanted rice.

2. MATERIALS AND METHODS

A field experiment was conducted during *kharif*, 2021 at All India Coordinated Research Project on Weed Management, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad with nine treatments laid out in randomized complete block design with three replications. The soil of the experimental site was sandy clay loam in texture. The treatments comprised of T_1: Penoxsulam 1.02% (20 g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) (RM) as post emergence *fb* hand weeding at 40 DAT, T_2: Penoxsulam 0.97% (20 g ha^{-1}) + butachlor (38.8%) @ 820 g ha^{-1} (RM) as post-emergence *fb* hand weeding at 40 DAT, T_3: Pyrazosulfuron ethyl 0.15 % (15 g ha^{-1})+ pretilachlor 6% (600 g ha^{-1}) (RM) as pre-emergence *fb* hand weeding at 40 DAT, T_4: Bensulfuron methyl 0.6 % (60 g ha^{-1}) + pretilachlor 6% (600 g ha^{-1}) GR (RM) as pre-emergence *fb* hand weeding at 40 DAT, T_5: Bispyribac sodium 10% SC 25 g ha^{-1} as post emergence *fb* hand weeding at 40 DAT, T_6: Triafamone 20% (44 g ha^{-1}) +ethoxysulfuron 10%

WG (22.5 g ha^{-1}) (RM) as post- emergence *fb* hand weeding at 40 DAT, T_7: Bispyribac sodium 10% SC 25 g ha^{-1}+penoxsulam 1.02% (20 g ha^{-1}) (tank mix) as post- emergence *fb* hand weeding at 40 DAT, T_8: Hand weeding at 20 and 40 DAT and T_9: Unweeded control. Rice variety 'Telangana Sona (RNR 15048)'was used for the experiment. The nursery was sown on 2nd August, 2021. The land was prepared by ploughing followed by through puddling. Seedlings of 25 days age were transplanted on 27th August, 2021 at a spacing of 15 cm x 10 cm. Recommended dose of fertilizer i.e., 120:60:40 kg N: P_2O5: K_2O as urea, single super phosphate and muriate of potash, respectively were applied. The entire P_2O_5 and half of K_2O were applied at sowing. Nitrogen was applied in three equal splits (1/3rd each at basal, maximum tillering and panicle initiation). The gross plot size was 5.8 m x 3.8m. Data on weed count and weed dry weight were taken from each plot on 30 and 60 DAT. The weeds were identified species-wise. Dry weights of weeds were taken from each plot by shade drying initially followed by oven drying at 60^{0-}C to a constant weight and expressed in g m^{-2}. Data on plant height, number of tillers at harvest, panicles m^{-2}, panicle length, test weight, grains per panicle, grain yield and straw yield were collected. Gross returns, net returns and Benefit-Cost ratio (B-C ratio) were calculated for each treatment and analyzed statistically.

3. RESULTS AND DISCUSSION

3.1 Weed Control

3.1.1 Weed density

Weed density was recorded at 30 and 60 DAT. Results showed significant differences among the herbicidal treatments for the weed count of grass, sedge and broad leaf species. Maximum weed density was recorded in unweeded control (T_9) at 30 and 60 DAT (Table 1). The data showed that hand weeding at 20 and 40 DAT (T_8) better resulted in controlling both monocot and dicot weeds at 30 DAT while at 60 DAT, the maximum reduction in weed count was observed with bispyribac sodium10% SC 25 g ha^{-1} as post-emergence *fb* hand weeding at 40 DAT (T_5) which was found to be on par with all other treatments and significantly superior over unweeded control. The results are in line with Teja et al. [2] who found that bensulfuron methyl 0.6% + pretilachlor 6% registered a lower number as well as dry weight of grassy, broadleaved, sedge and total weeds at 45 DAT.

3.1.2 Weed dry weight

The highest weed dry weight was recorded in unweeded control (T_9) at 30 and 60 DAT that received practically no weed control measures (Table 2). Herbicidal weed control treatments significantly affected all categories of weeds (grass, sedges and broad-leaved) and the lowest weed dry weight was recorded in the plots that received bensulfuron methyl 0.6 % (60 g ha^{-1}) + pretilachlor 6% (600 g ha^{-1}) GR as pre-emergence *fb* hand weeding at 40 DAT (T_4). It was on par with triafamone 20% (44 g ha^{-1}) +ethoxysulfuron 10% WG (22.5 g ha^{-1}) as post-emergence *fb* hand weeding at 40 DAT (T_6), hand weeding at 20 and 40 DAT (T_8) and penoxsulam 1.02% (20g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) as post-emergence *fb* hand weeding at 40 DAT (T_1). At 60 DAT, hand weeding at 20 and 40 DAT (T_8) recorded lowest weed dry weight probably due to effective control of first flush of weeds from 15-45 DAT but penoxsulam 0.97% (20 g ha^{-1}) + butachlor (38.8%) @ 820 g ha^{-1}as post- emergence *fb* hand weeding at 40 DAT (T_2), bispyribac sodium 10% SC 25 g ha^{-1}+penoxsulam 1.02% (20g ha^{-1}) (tank mix) as post- emergence *fb* hand weeding at 40 DAT (T_7), penoxsulam 1.02 % (20g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) as post- emergence *fb* hand weeding at 40 DAT (T_1) and bensulfuron methyl 0.6 % (60 g ha^{-1}) + pretilachlor 6% (600 g ha^{-1}) GR as pre-emergence *fb* hand weeding at 40 DAT (T_4) were also on par with hand weeding twice. Nazir et al. [9] also evaluated Butachlor @ 1500 g a.i ha^{-1}; Penoxsulam @ 22.5 g a.i ha^{-1}; Pyrazosulfuron ethyl + pretilachlor @ 15 and 600 g a.i ha^{-1}; Bensulfuron methyl + pretilachlor @ 60 and 600 g a.i ha^{-1} in transplanted rice at Wadora-Sopore, Jammu and Kashmir. They found that all herbicides considerably reduced dry weed biomass, but penoxsulam herbicide showed the greatest reduction in dry weed biomass and proved superior against complex weed flora.

3.2 Crop Growth and Yield Attributes

3.2.1 Plant height

The herbicide mixtures or hand weeding did not show any significant influence on the plant height of rice at harvest (Table 3).

Table 1. Total weed density (No/m²) and weed dry weight (g/m²) in transplanted rice as influenced by herbicides and herbicide mixtures

Treatment		Total weed count (No./m^2)		Total Weed dry weight (g/m^2)	
		30 DAT	**60 DAT**	**30 DAT**	**60 DAT**
T_1	Penoxsulam + cyhalofop butyl (RM) *fb* HW at 40 DAT	4.65 (20.67)	2.14 (3.67)	4.19 (16.67)	2.92 (7.60)
T_2	Penoxsulam + butachlor (RM) *fb* HW at 40 DAT	4.58 (20.00)	2.40 (4.67)	4.50 (19.33)	2.72 (6.67)
T_3	Pyrazosulfuron ethyl + pretilachlor (RM) *fb* HW at 40 DAT	4.57 (20.00)	2.28 (4.33)	5.45 (29.00)	3.32 (10.33)
T_4	Bensulfuron methyl + pretilachlor GR (RM) as *fb* HW at 40 DAT	3.59 (12.00)	2.29 (4.33)	3.89 (14.33)	3.09 (8.70)
T_5	Bispyribac sodium *fb* HW at 40 DAT	4.54 (19.67)	1.99 (3.33)	5.16 (25.67)	3.34 (10.20)
T_6	Triafamone + ethoxysulfuron (RM) *fb* HW at 40 DAT	4.96 (23.67)	2.14 (3.67)	3.97 (15.00)	3.40 (10.73)
T_7	Bispyribac sodium + penoxsulam (tank mix) *fb* HW at 40 DAT	5.75 (32.33)	2.00 (3.00)	4.46 (19.00)	2.78 (6.73)
T_8	HW at 20 and 40 DAT	2.87 (7.33)	2.14 (3.67)	4.00 (15.00)	2.48 (5.27)
T_9	Unweeded control	9.06 (81.33)	9.65 (92.33)	7.92 (62.00)	10.45 (108.33)
SE(m)±		**0.232**	**0.253**	**0.269**	**0.268**
CD (P=.05)		**0.700**	**0.766**	**0.815**	**0.811**

T_1 - Penoxsulam 1.02% (20 g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) (RM) as post emergence fb hand weeding at 40 DAT.
T_2 - Penoxsulam 0.97% (20 g ha^{-1}) + butachlor (38.8%) 820 g ha^{-1}(RM) as post- emergence fb hand weeding at 40 DAT.
T_3 – Pyrazosulfuron ethyl 0.15 % (15 g ha^{-1}) + pretilachlor 6% (600 g ha^{-1}) (RM) as pre-emergence fb hand weeding at 40 DAT.
T_4 - Bensulfuron methyl 0.6 % (60 g ha^{-1}) + pretilachlor 6% (600 g ha^{-1}) GR (RM) as pre-emergence fb hand weeding at 40 DAT.
T_5 - Bispyribac sodium 10% sc 25 g ha^{-1} as post emergence fb hand weeding at 40 DAT.
T_6 - Triafamone 20% (44 g ha^{-1}) + ethoxysulfuron 10% WG (22.5 g ha^{-1}) (RM) as post- emergence fb hand weeding at 40 DAT.
T_7 - Bispyribac sodium 10% sc 25 g ha^{-1}+ penoxsulam 1.02% (20g ha^{-1}) (tank mix) as post- emergence fb hand weeding at 40 DAT.
T_8 - Hand weeding at 20 and 40 DAT.
T_9 - Unweeded control

3.2.2 Number of tillers m^{-2}

Higher number of tillers m^{-2} was registered with penoxsulam 1.02% (20g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) as post-emergence *fb* hand weeding at 40 DAT (T_1) which was on par with triafamone 20% (44 g ha^{-1}) + ethoxysulfuron 10% WG (22.5 g ha^{-1}) as post-emergence *fb* hand weeding at 40 DAT (T_6), bispyribac sodium 10% SC 25 g ha^{-1}+penoxsulam 1.02% (20g ha^{-1}) (tank mix) as post- emergence *fb* hand weeding at 40 DAT (T_7), penoxsulam 0.97% (20 g ha^{-1}) + butachlor (38.8%) @ 820 g ha^{-1}as post-emergence *fb* hand weeding at 40 DAT (T_2) and bensulfuron methyl 0.6 % (60 g ha^{-1}) + pretilachlor 6% (600 g ha^{-1}) GR as pre-emergence *fb* hand weeding at 40 DAT (T_4) while the lower number of tillers m^{-2} was obtained with unweeded control (T_9) (Table 2).

3.2.3 Number of panicles m^{-2}

Similar to number of tillers m^{-2}, the number of panicles m^{-2} was also higher with penoxsulam 1.02% (20g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) as post emergence *fb* hand weeding at 40 DAT (T_1) (Table 2). It was found to be on par with bispyribac sodium 10% SC 25 g ha^{-1}+ penoxsulam 1.02% (20 g ha^{-1}) (tank mix) as post- emergence *fb* hand weeding at 40 DAT (T_7), bensulfuron methyl 0.6 % (60 g ha^{-1}) +

pretilachlor 6% (600g ha^{-1}) GR as pre-emergence *fb* hand weeding at 40 DAT (T_4) and pyrazosulfuronethyl 0.15 % (15 g ha^{-1})+ pretilachlor 6% (600g ha^{-1}) as pre-emergence *fb* hand weeding at 40 DAT (T_3). Unweeded control (T_9) recorded the lower number of panicles m^{-2}.

3.2.4 Panicle length

Among the treatments, the maximum panicle length was observed with pyrazosulfuron ethyl 0.15 % (15 g ha^{-1}) + pretilachlor 6% (600g ha^{-1}) as pre-emergence *fb* hand weeding at 40 DAT (T_3) which was on par with bensulfuron methyl 0.6 % (60 g ha^{-1}) + pretilachlor 6% (600g ha^{-1}) GR as pre-emergence *fb* hand weeding at 40 DAT (T_4), hand weeding at 20 and 40 DAT (T_8), bispyribac sodium 10% SC 25 g ha^{-1}+penoxsulam 1.02% (20g ha^{-1}) (tank mix) as post- emergence *fb* hand weeding at 40 DAT (T_7), penoxsulam 1.02% (20g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) as post emergence *fb* hand weeding at 40 DAT (T_1) and penoxsulam 0.97% (20 g ha^{-1}) + butachlor (38.8%) @ 820 g ha^{-1}as post-emergence *fb* hand weeding at 40 DAT (T_2).The lower panicle length was recorded with unweeded control (T_9).

3.2.5 Grains panicle^{-1}

The study revealed that the herbicides and their combinations significantly affected the number of grains per panicle (Table 3). Among the various treatments, the higher number of grains per panicle was recorded in plots sprayed with penoxsulam 1.02% (20 g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) as post-emergence *fb* hand weeding at 40 DAT (T_1) and was in equivalence with pyrazosulfuronethyl 0.15 % (15 g ha^{-1})+ pretilachlor 6% (600g ha^{-1}) as pre-emergence *fb* hand weeding at 40 DAT (T_3), bispyribac sodium 10% SC 25 g ha^{-1} as post-emergence *fb* hand weeding at 40 DAT (T_5), bensulfuron methyl 0.6 % (60 g ha^{-1}) + pretilachlor 6% (600g ha^{-1}) GR as pre-emergence *fb* hand weeding at 40 DAT (T_4), bispyribac sodium 10% SC 25 g ha^{-1}+penoxsulam 1.02% (20g ha^{-1}) (tank mix) as post- emergence *fb* hand weeding at 40 DAT (T_7), penoxsulam 0.97% (20 g ha^{-1}) + butachlor (38.8%) @ 820 g ha^{-1}as post- emergence *fb* hand weeding at 40 DAT (T_2) and triafamone 20 % (44 g ha^{-1}) + ethoxysulfuron 10% WG (22.5 g ha^{-1})as post-emergence *fb* hand weeding at 40 DAT (T_6).

3.2.6 Test weight

A perusal of the data inTable 2 shows that penoxsulam 1.02% (20g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) as pos- emergence *fb* hand weeding at 40 DAT (T_1) produced a higher test weight than unweeded control (T_9). However, this result was comparable to T_2, T_3, T_6, T_8 and T_4 treatments.

3.3 Yield

3.3.1 Grain yield

A critical look at the data indicates that the grain yield of rice was influenced significantly due to the different herbicides alone or in combination (Table 3). Rice grain yield was significantly higher with penoxsulam 1.02% (20g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) as post-emergence *fb* hand weeding at 40 DAT (T_1) which was similar with the rest of the herbicide treatments tested during *kharif,* 2021. This might be due to the higher crop growth of rice due to lower weed competition. This resulted in large amounts of photosynthates accumulation leading to better yield attributes, finally higher yield. The yield of rice also depends on partitioning ability of photosynthates from source to sink *i.e.*, developing grains which leads to increased yield. All the yield promoting characters were significantly higher with penoxsulam 1.02% (20g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) as post emergence *fb* hand weeding at 40 DAT (T_1) due to better partitioning of photosynthates to developing grains. The lower grain yield was registered under unweeded control (T_9). Similar results were obtained by Chaudhary et al. [10] who observed increased grain yield of transplanted rice with the application of pretilachlor (750 g a.i. ha^{-1}) at 3 DAT + penoxulam (22 g a.i. ha^{-1}) at 20 DAT.

3.3.2 Straw yield

It is apparent from the data that herbicide treatments have shown a significant impact on straw yield (Table 3). The highest straw yield was achieved with the application of penoxsulam 1.02% (20g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) as post- emergence *fb* hand weeding at 40 DAT (T_1), however unweeded control (T_9) recorded the lower straw yield in rice. Post-emergence application of herbicides augmented the growth and improved the yield structure thereby yield of rice which might be due to reduced competition from weeds for a prolonged period of crop growth. These results are in line with Rao et al. [11] who reported that without the application of post-emergence herbicides, the rice yield may reduce by 9 to 60%.

Table 2. Yield attributes in transplanted rice as influenced by herbicides and herbicide mixtures

Treatment		Plant height at harvest (cm)	Tillers at harvest (No/m^2)	No. of panicles/m^2	Panicle length (cm)	No. of grains/ panicle	Test weight (g)
T_1	Penoxsulam + cyhalofop butyl (RM) *fb* HW at 40 DAT	71.41	257	218	16.11	162	13.67
T_2	Penoxsulam + butachlor (RM) *fb* HW at 40 DAT	68.59	223	188	15.97	143	13.57
T_3	Pyrazosulfuron ethyl + pretilachlor (RM) *fb* HW at 40 DAT	74.23	207	195	17.48	155	13.43
T_4	Bensulfuron methyl + pretilachlor GR (RM) as *fb* HW at 40 DAT	70.67	218	196	16.62	151	13.10
T_5	Bispyribac sodium *fb* HW at 40 DAT	71.82	210	191	15.20	153	12.90
T_6	Triafamone + ethoxysulfuron (RM) *fb* HW at 40 DAT	71.20	227	195	15.86	140	13.37
T_7	Bispyribac sodium + penoxsulam (tank mix) *fb* HW at 40 DAT	68.61	225	198	16.22	144	12.90
T_8	HW at 20 and 40 DAT	72.65	182	161	16.50	109	13.23
T_9	Unweeded control	75.83	134	88	12.59	83	11.77
	SE(m)±	**1.982**	**13.75**	**7.45**	**0.57**	**7.96**	**0.25**
	CD (P=.05)	**NS**	**41.59**	**22.62**	**1.74**	**24.07**	**0.76**

3.3.3 Harvest index

Statistical analysis of data shows that there was a significant effect of herbicide treatments on the harvest index of *kharif* rice crop which is presented in Table 3. The treatment bensulfuron methyl 0.6 % (60 g ha^{-1}) + pretilachlor 6% (600g ha^{-1}) GR as pre-emergence *fb* hand weeding at 40 DAT (T_4) recorded the highest harvest index which was at par with rest of the treatments while unweeded control recorded the lowest harvest index (T_9).

3.4 Economics

3.4.1 Gross returns

With the application of penoxsulam 1.02% (20g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) as post-emergence *fb* hand weeding at 40 DAT (T_1), higher gross returns were noticed which was similar with other herbicidal treatments and hand weeding at 20 and 40 DAT (Table 3). The unweeded control (T_9) recorded lower gross returns.

3.4.2 Net returns

When compared to other herbicide combinations, penoxsulam 1.02% (20g ha^{-1}) + cyhalofop buty l 5.1% (100 g ha^{-1}) as post emergence *fb* hand weeding at 40 DAT (T_1) considerably increased the monetary returns of rice and was found to be on par with bispyribac sodium 10% SC 25 g ha^{-1} as post emergence *fb* hand weeding at 40 DAT (T_5), triafamone 20% (44 g ha^{-1}) + ethoxysulfuron

Table 3. Yield and economics in transplanted rice as influenced by herbicides and herbicide mixtures

Treatment		Grain yield (Kg/ha)	Straw yield (kg/ha)	HI	COC	GR	NR	B-C ratio
T_1	Penoxsulam + cyhalofop butyl (RM) *fb* HW at 40 DAT	5596	6710	45.4	65745	123107	57362	1.87
T_2	Penoxsulam + butachlor (RM) *fb* HW at 40 DAT	5403	5981	47.4	64750	117861	53111	1.82
T_3	Pyrazosulfuron ethyl + pretilachlor (RM) *fb* HW at 40 DAT	5261	6413	45.0	65250	115949	50699	1.78
T_4	Bensulfuron methyl + pretilachlor GR (RM) as *fb* HW at 40 DAT	5436	5803	48.3	65375	118158	52783	1.81
T_5	Bispyribac sodium *fb* HW at 40 DAT	5463	6475	45.7	64750	120025	55275	1.85
T_6	Triafamone + ethoxysulfuron (RM) *fb* HW at 40 DAT	5490	6237	46.8	66750	120070	53321	1.80
T_7	Bispyribac sodium + penoxsulam (tank mix) *fb* HW at 40 DAT	5448	6120	47.0	68500	119013	50513	1.74
T_8	HW at 20 and 40 DAT	5146	6594	43.8	68500	114043	45544	1.66
T_9	Unweeded control	1066	2270	31.9	64750	25440	-39310	0.39
	SE(m)±	**233**	**206**	**0.8**	**-**	**4887**	**4887**	**0.07**
	CD (P=.05)	**706**	**622**	**2.4**	**-**	**14778**	**14779**	**0.22**

10% WG (22.5 g ha^{-1})as post-emergence *fb* hand weeding at 40 DAT (T_6), penoxsulam 0.97 % (20 g ha^{-1}) + butachlor (38.8%) @ 820 g ha^{-1}as post- emergence *fb* hand weeding at 40 DAT (T_2) and bensulfuron methyl 0.6% (60 g ha^{-1}) + pretilachlor 6% (600 g ha^{-1}) GR as pre-emergence *fb* hand weeding at 40 DAT (T_4) as shown in Table 3. Lower monetary returns was seen in unweeded control (T_9).

3.4.3 B-C ratio

Penoxsulam 1.02% (20g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) as post-emergence *fb* hand weeding at 40 DAT (T_1) gave maximum B-C ratio while the lower B-C ratio was observed with unweeded control (T_9) (Table 3). The next best herbicidal treatment was bispyribac sodium 10% sc 25 g ha^{-1} as post emergence *fb* hand weeding at 40 DAT and penoxsulam 0.97% (20 g ha^{-1}) + butachlor (38.8%) @ 820 g ha^{-1}as post-emergence *fb* hand weeding at 40 DAT.

Our results establish that herbicide mixtures were highly effective in controlling weed growth and produced higher yields of rice. Menon [12] also evaluated the herbicide mixtures in wet-seeded rice i.e., triafamone + ethoxy sulfuron (PM), cyhalofop-butyl + penoxsulam (PM) and fenoxaprop-p-ethyl + ethoxysulfuron (tank mix) and found that ready mix herbicides were more effective. These herbicide mixtures can control all type of weeds in a single spray which is economical as well as saves time for the farmers. Further, herbicides used in combination can reduce the probability of herbicide resistance in weeds [13]. Similar results were reported by Choudhary et al. [14] in wheat; Mahajan and Chouhan [15] in direct-seeded rice; Susha et al. [16] in maize-wheat cropping system.

4. CONCLUSION

This experiment has shown that penoxsulam 1.02% (20 g ha^{-1}) + cyhalofop butyl 5.1% (100 g ha^{-1}) (RM) as post-emergence *fb* hand weeding at 40 DAT increased the growth, yield components, yield and monetary returns of transplanted rice with reduced weed density and weed dry weight but closely followed by bispyribac sodium 10% SC 25 g ha^{-1} as post emergence *fb* hand weeding at 40 DAT and penoxsulam 0.97% (20 g ha^{-1}) + butachlor (38.8%) 820 g ha^{-1} (RM) as post- emergence *fb* hand weeding at 40 DAT.

ACKNOWLEDGEMENTS

The authors are thankful to AICRP on Weed Management, DWR, Jabalpur and PJTSAU for providing funds towards conduct of the research work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/94740