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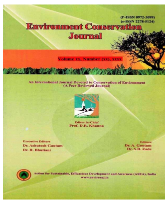

Influence of weed management practices on direct-seeded rice grown under rainfed and irrigated agroecosystems

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ABSTRACT

Rice seedlings and weeds emerge concurrently in direct-seeded rice (DSR) production systems, while there is no flooding water to inhibit weed germination, emergence and development at crop emergence. Because of this, weeds are considered the biggest living barrier in DSR and significantly reduce yield. The purpose of the research was to devise an approach for management of weeds in the direct-seeded rice crop cultivated under various agroecosystems, while optimizing growth and production utilizing herbicides or herbicidal combinations. The impacts of several weed management techniques were assessed to determine the most efficient and cost-effective approach of managing weeds in DSR at the CoA, JNKVV, Jabalpur (MP) during 2019 rainy season under spilt plot design with 2 main plot treatments viz., rainfed agroecosystem, irrigated agroecosystem and 8 sub-plot treatments, i.e. different herbicide treatments with hand weeding and weedy check. Further growth parameters as well as yield attributes were documented. Conventional statistical techniques were used to evaluate the data. Bispyribac sodium at the dose of 25 g/ha efficiently controlled both narrow and broad leaved weeds under agroecosystems. Highest growth as well as yield parameters were recorded for irrigated agroecosystems compared to rainfed agroecosystems. The treatment with bispyribac sodium at the dose of 25 g/ha produced the greatest values for growth and yield indices as well as the maximum yield (3.68 t/ha), with the exception of manual weeding.

Introduction

Rice, an important food crop is grown on 161 million hectares in more than 100 nations (FAOSTAT, 2020). Asia itself produces and uses up 90 per cent of the total world's rice, which provides up to 75% of the calories needed for 520 million people (Priya *et al.,* 2019). The ever-increasing demands of the growing population can only be met by increasing the worldwide rice output by 26% and 50% by 2035 and 2050, respectively (IRRI, 2020). China accounts for 28% while India account for 22% out of the total global output of rice. The area shared by the rice-growing ecosystems is approximately 44 million ha, of which upland contributes 7 million ha and lowland contributes 17 million ha, respectively. India's overall production is 104.3 million tonnes (MT), and national productivity is 2.40 t/ha (GoI, 2018). Transplanted rice has several difficulties which included high demand of water (1000-2000 mm) for flooding as well as for puddling operations (Materu *et al*., 2018) and many farmers, especially marginal and small farmers, find it to be unaffordable due to its high energy consumption of 5630 to 8448 MJ/ha (Neog *et al*., 2015), as well as its nearly 15-20% higher labour inputs (Bhatt *et al*., 2016; Saharawat *et al*., 2010).

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A new method of growing upland rice called direct-seeded rice requires less irrigation water, labour, and energy compared to transplanted rice. Rice crops are established by simply spreading seeds in non-puddled, non-saturated soil (Liu *et al*., 2014). Direct-seeded rice does not include operations such as seeding, nursery, seedling care, removing, bundling, transferring, and transplanting (Nagargade *et al*., 2018). Direct-seeded rice can increase yield, decrease fertilizer and land preparation costs, increase household income, and improve soil productivity (Devkota *et al*., 2020). Additional advantages of DSR include quicker and more effective planting, better soil quality, high water shortage tolerance, decreased methane emissions, and even higher income in places with a secure water system (Singh *et al*., 2016). It has various advantages, including the need for less water (35–57%) and less labour (67%), respectively, compared to rice transplantation. This system saves labour from nursery preparation and allows the entire cost to be decreased by 11.2 per cent. In terms of working hours, this approach reduces labour requirements by more than 25% (Asghar *et al*., 2018). DSR has several advantages and may be a viable alternative to traditional transplantation; however, the main drawbacks are low germination, uneven crop standing, and significant weed infestation (Raj *et al.,* 2017).

A significant obstacle to the effectiveness of the direct seeded rice technology is weed infestation (Zia-Ul-Haq *et al*., 2019). Crop establishment methods, such as transplanting versus direct sowing, resulted in significant changes in weed flora composition. In comparison to flooded transplanted rice, weeds flourish fast in DSR (Rathika *et al.,* 2020). Yield losses under DSR are anticipated to reach up to 75%, which represents more than 30% of the overall expenditures associated with rice cultivation (Rao *et al.,* 2007). In DSR, weed competition peaked between 14 to 41 days after seeding.Herbicides, manual weeding techniques, or a combination of the two can be very effectively used for managing or controlling complex weed flora in rice ecosystem. However, labour scarcity, rising costs, and laborious nature of hand weeding, chemicals have replaced it. Herbicides are becoming more common due to their quick results and reduced price in direct-seeded rice (Patel *et al*., 2018). Herbicides provide more accessible, timelier, cost-effective, and convenient weed control in rice, compared to the higher expense, drudgery, and lesser efficacy of other weed control solutions (Sen *et al*., 2020). DSR is now feasible, thanks to the new more efficiency and low dose herbicides, especially with short duration high yielding varieties (Mortimer *et al.,* 2008). A group of weed species can be effectively controlled by applying certain selective herbicides. As a result, alternative herbicides or herbicide mixtures must be evaluated for managing different types of weeds in DSR. Therefore, current research aimed to assess the efficacy of different herbicides and their combinations against various weed flora under rainfed and irrigated agroecosystems, as well as how these factors affected growth and production.

Material and Methods

During the 2019 rainy season, a research trial was carried out at College of Agriculture, JNKVV, Jabalpur (MP). The 16 different treatment combinations were included in the experimental trial with two main treatments, i.e., agroecosystems viz., rainfed and irrigated and eight sub-treatments, i.e., different weed management practices viz., bispyribac sodium 25 g/ha, fenoxaprop-p-ethyl 60 g/ha, fenoxaprop-p-ethyl + penoxsulam 60 + 26.7 g/ha, cyhalofop + penoxsulam 135 + 26.7 g/ha, bispyribac sodium + metsulfuron methyl + chlorimuron ethyl 25+4 g/ha, triafamone + ethoxysulfuron 40+20 g/ha, weedy check and hand weeding (two) at 20 and 40 DAS. These treatment combinations were necessary to evaluate the most effective herbicide combination for the control of complex weeds under the rainfed and irrigated agro-ecosystems and to carry out a comparative analysis with hand weeding and weedy check treatments. Three replications were used and the design was split-plot. Post-emergence application of herbicides was made. At the meterorological observatory, JNKVV, Jabalpur, climatic observation was recorded. Figure 1 displays the climatic scenario of the experimental site.

In a weedy plot, weeds were permitted to grow all through the crop's growth cycle alongside the crop. A quadrate (0.25 square meters) was used to measure dry weight and number of weeds as suggested by Mishra and Misra (1997). To normalise the distribution of weed number and dry weight, the square root type of transformation was used. WCE was calculated using an equation Kumar *et al*. (2016) proposed.

$$\boldsymbol{WCE}(\%) = \frac{\boldsymbol{DWC - DWT}}{\boldsymbol{DWC}}\boldsymbol{x100}$$

All other agronomic procedures were carried out in accordance with recommendations (Pathak *et al.*, 2011). Economic analysis was carried out based upon current market value of inputs used and the output from each treatment (CIMMYT, 1998). The effect of agro-ecosystems and weed management practices was analysed in split-plot design. Treatment effects were presented by making tables of means for different parameters with appropriate standard error (SEm+) and least significant difference (0.05) (Steel and Torrie, 1980). Correlation analysis was done for estimating the extent of relationship between independent variables and dependent variable.

Results and Discussion

Soil properties

The soil of the site had a sandy clay-loam texture, a pH of 6.40, and had a medium amount of organic C (0.72%), available N (293.65 kg/ha), available P (17.50 kg/ha), as well as available P (257.47 kg/ha).

Weed species

Broad-leaved, narrow-leaved weeds and sedges were abundant in research field. Under rainfed agroecosystems, the relative density of weeds was *Echinochloa colona* L. (30%), *Alternanthera sessilis* L. (26%), *Cyperus iria* L. (18.9%) and *Cynodon dactylon* L. (18.4%). Whereas, in irrigated agroecosystems, the relative density of weeds was *Echinochloa colona* L. (28.6%), *Alternanthera sessilis* L. (25%), *Cyperus iria* L. (18%) and *Cynodon dactylon* L. (17.9%).

Weed density and dry weight

In rainfed and irrigated agroecosystems at 90 DAS, weed density was significantly reduced by weed management methods particularly in comparison to weedy check plot (Table 1). The agroecosystems did not have a significant impact on weed density and weed dry weight. However, the maximum density of weeds was noticed there in rainfed agroecosystems compared to irrigated agroecosystems due to aerobic conditions presented in rainfed agroecosystems that are beneficial for weed growth. Among herbicides, bispyribac sodium 25 g/ha controlled all the types of weeds successfully and recorded a lower weed population and was found statistically at par with fenoxaprop-p-ethyl + penoxsulam 60 + 26.7 g/ha and Cyhalofop + penoxsulam 135+26.7 g/ha. At the same time, weedy check recorded significantly higher weed population. In the specific case of the interaction effect, bispyribac sodium 25 g/ha applied to irrigated agroecosystems resulted in a minimum weed population of all dominated weeds. The reduction in weed population in this treatment was primarily attributable to successful weed management without causing poisoning symptoms in rice plants. Herbicide efficiency differences can be linked to variations in weed flora composition and emergence patterns throughout crop development (Adigun *et al.,* 2005). Moreover, Mahajan *et al.* (2009) observed that bispyribac sodium was efficient in direct seeded rice cultures. Sekhar *et al*. (2020); Verma *et al*. (2022) also found that byspyribac sodium 25 g/ha considerably decreased weed density when compared to other herbicidal treatments and effectively controlled broad-leaved weeds, narrow-leaved weeds and sedges also. Similarly, treatments also significantly affected weed dry weight at 90 DAS (Table 2). Among agroecosystems, irrigated rice recorded a minimum weed dry weight than rainfed rice. The amount of weed biomass was found lowest in hand-weeded plots and highest in weedy check plots. The herbicidal treatment of bispyribac sodium 25 g/ha was successful in decreasing the biomass of all weeds and was determined to be efficacious for all weeds. The lowest dry biomass of grassy, sedge, and broad-leaved weeds were recorded when bispyribac sodium was utilized at a dose of 25 g/ha in irrigated agroecosystems. (Singh *et al*., 2014; Menon, 2019).

Weed control efficiency

Under treatments, there was a strong inverse association between weed control efficiency and weed dry weight. Hand weeding treatment registered maximum efficiency in rainfed (97%) and irrigated agroecosystems (97.4%) than all other treatments at 90 DAS (Figure 2) due to the production of less dry matter of the weeds over the weedy check. All herbicidal treatments reduced weed growth, but bispyribac sodium 25 g/ha had

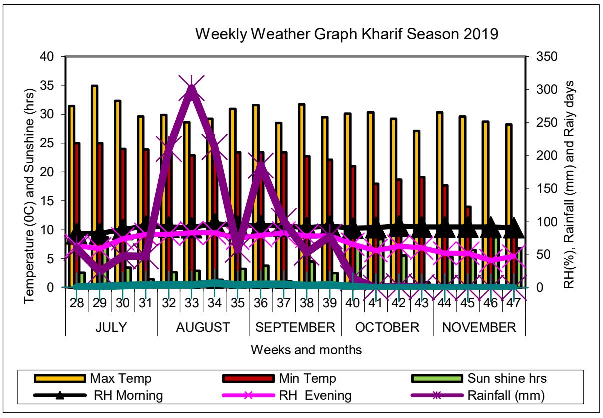

Figure 1: Graphical representation of weekly meteorological data from July 2019 to November 2019

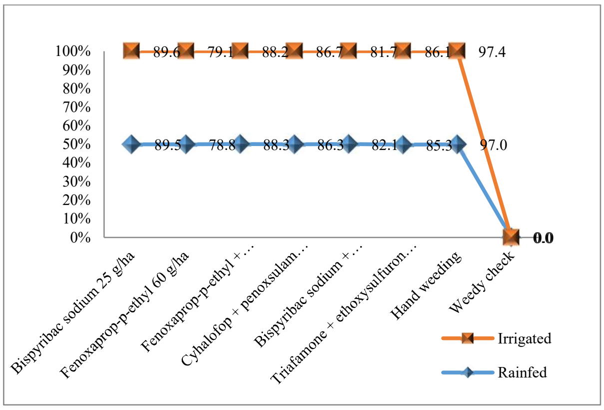

Figure 2: Weed control efficiency under rainfed and irrigated agroecosystems

Table 1: Influence of weed control practices on density of weeds under rainfed and irrigated agro ecosystems at 90 DAS

Treatments	Weed density (no./m²)			
	Echinochloa colona	***Alternanthera sessilis***	***Cyperus iria***	***Cynodon dactylon***
Agroecosystems				
Rainfed	2.82 (10.0)	2.71 (9.0)	2.61 (7.9)	2.38 (6.7)
Irrigated	2.67 (8.8)	2.57 (8.0)	2.49 (7.0)	2.27 (6.1)
CD (P=0.05)	NS	NS	NS	NS
Weed control practices				
Bispyribac sodium 25 g/ha	1.99 (3.6)	1.79 (2.9)	1.88 (3.2)	1.57 (2.1)
Fenoxaprop-p-ethyl 60 g/ha	2.84 (7.7)	2.81 (7.5)	2.67 (6.8)	2.27 (4.9)
Fenoxaprop-p-ethyl + penoxsulam 60+26.7 g/ha	2.06 (3.9)	2.11 (4.1)	2.12 (4.1)	1.98 (3.6)
Cyhalofop + penoxsulam 135+26.7 g/ha	2.41 (5.5)	2.24 (4.8)	2.30 (5.0)	2.03 (3.9)
Bispyribac sodium + metsulfuon methyl + chlorimuron ethyl 25+4 g/ha	2.73 (7.1)	2.58 (6.3)	2.57 (6.3)	2.16 (4.4)
Triafamone + ethoxysulfuron 40+20 g/ha	2.44 (5.7)	2.38 (5.4)	2.34 (5.2)	2.07 (4.2)
Hand weeding	1.04 (0.6)	1.20 (1.0)	1.23 (1.1)	1.33 (1.3)
Weedy check	6.43 (41.0)	6.03 (36.0)	5.32 (27.9)	5.20 (26.7)
CD (P=0.05)	0.46	0.47	0.50	0.57

Table 2:Influence of weed control practices on dry weight of weeds under rainfed and irrigated agro ecosystems at 90 DAS.

Treatments	Weed dry weight (g/m²)			
	Echinochloa colona	***Alternanthera sessilis***	***Cyperus iria***	***Cynodon dactylon***
Agroecosystems				
Rainfed	3.01 (11.2)	2.93 (10.5)	2.83 (9.6)	2.62 (7.9)
Irrigated	2.92 (10.6)	2.84 (9.9)	2.73 (9.0)	2.51 (7.3)
CD (P=0.05)	NS	NS	NS	NS
Weed control practices				
Bispyribac sodium 25 g/ha	2.32 (5.0)	2.25 (4.7)	2.16 (4.3)	1.87 (3.2)
Fenoxaprop-p-ethyl 60 g/ha	3.10 (9.3)	3.05 (8.9)	2.93 (8.3)	2.65 (6.8)
Fenoxaprop-p-ethyl + penoxsulam 60+26.7 g/ha	2.34 (5.2)	2.30 (5.0)	2.20 (4.6)	2.13 (4.3)
Cyhalofop + penoxsulam 135+26.7 g/ha	2.52 (6.0)	2.43 (5.7)	2.40 (5.4)	2.25 (4.8)
Bispyribac sodium + metsulfuon methyl + chlorimuron ethyl 25+4 g/ha	2.87 (8.0)	2.80 (7.7)	2.75 (7.3)	2.46 (5.9)
Triafamone + ethoxysulfuron 40+20 g/ha	2.57 (6.2)	2.53 (6.0)	2.41 (5.5)	2.32 (5.0)
Hand weeding	1.13 (0.8)	1.16 (0.9)	1.25 (1.1)	1.40 (1.5)
Weedy check	6.85 (46.5)	6.58 (43.1)	6.18 (37.8)	5.43 (29.1)
CD (P=0.05)	0.47	0.48	0.51	0.55

greatest amount of suppression of weeds, *fb* fenoxaprop-p-ethyl + penoxsulam 60 g/ha *fb* cyhalofop + penoxsulam 135 g/ha. It might result from wide spectrum weed control. Fenoxaprop-p-ethyl 60 g/ha is primarily effectual against grassy weeds only and thus, had lowest weed control efficiency. Interaction among the irrigated agroecosystem and herbicidal treatment bispyribac sodium 25 g/ha achieved higher (89.5%) weed control efficacy (Kaur *et al*., 2015). The results are in corroboration with the findings of Narolia *et al.* (2014).

Crop growth parameters

The rate of growth parameters has a genuinely significant impact on the ultimate yield of the plant, which is influenced by biotic and abiotic factors. The growth characteristics of DSR were greatly impacted by treatments. The information on plant growth characteristics at 90 DAS, including plant height, plant population, plant dry weight, and the number of tillers, as impacted by various weed management measures is shown in Table 3. In the case of the growth characteristics, the rainfed rice exhibited a minimum number of growth parameters than irrigated rice. This may be because of moisture stress under the rainfed agroecosystem, as it suffered abiotic stress during the reproductive stage, which affected growth parameters.

The findings showed that hand weeding produced the highest plant populations, plant heights, plant biomass, and number of tillers among the various weed management methods. In contrast, minimum values of these parameters were observed in weedy check plots. However, bispyribac sodium 25 g/ha recorded maximum values of all the growth parameters among all the herbicidal treatments, which were at par with fenoxaprop-p-ethyl + penoxsulam 60+26.7 g/ha. It is primarily because bispyribac sodium has a broad-spectrum ability to suppress grasses, sedges, and broad-leaved weeds, fostering favourable conditions for crop growth (Patel *et al.,* 2018; Singh *et al.,* 2016).

Table 3: Influence of weed control practices on growth characteristics of direct seeded rice under rainfed and irrigated agro ecosystems at 90 DAS

Treatments	Plant Population/m^2		Plant height (cm)		Plant biomass (g/m^2)		Number of tillers/m^2	
	RF	IR	RF	IR	RF	IR	RF	IR
Bispyribac sodium 25 g/ha	153	153	81.3	85.0	1118	1282	359	376
Fenoxaprop-p-ethyl 60 g/ha	138	138	75.6	79.3	811	933	310	327
Fenoxaprop-p-ethyl + penoxsulam 60+26.7 g/ha	150	151	80.0	84.3	1000	1207	350	370
Cyhalofop + penoxsulam 135+26.7 g/ha	143	145	78.8	82.5	968	1122	343	361
Bispyribac sodium + metsulfuon methyl + chlorimuron ethyl 25+4 g/ha	139	140	76.0	80.3	836	959	322	335
Triafamone + ethoxysulfuron 40+20 g/ha	141	142	77.1	81.0	920	1051	335	350
Hand weeding	156	157	83.0	87.3	1195	1513	369	392
Weedy check	129	130	74.0	78.0	580	723	302	307
CD (P=0.05)	2.28		2.64		2.52		2.30	

RF= Rainfed, IR= Irrigated

Under irrigated agroecosystems, growth parameters viz., plant population (153), plant height (85.0 cm), plant biomass (1282 g) and the number of tillers (376) exhibited higher values with bispyribac sodium 25 g/ha application. The observed increases in these growth characteristics relative to weedy control point to the efficacy of various weed control measures in reducing weed growth, which subsequently reduced weed crop competition for any of the growth variables. Similar findings were also reported by Anwar *et al*. (2011) and Khaliq *et al.* (2012).

Yield attributing characters and yield

The information about no. of grains presented in each panicle, weight per 1000 seeds and grain yield varied significantly amongst the weed-management techniques (Table 4). Irrigated rice exhibited higher yields attributing values and grain yield than rainfed rice among agro-ecosystems, and it was due to water stress which affected the expansion and

Table 4: Influence of weed control practices on yield attributes, grain yield and economics of direct seeded rice under rainfed and irrigated agro ecosystems

Treatments	Grains/panicle		1000-seed weight (g)		Grain yield(t/ha)		NMR (x10^3 Rs/ha)	
	RF	IR	RF	IR	RF	IR	RF	IR
Bispyribac sodium 25 g/ha	71.0	84.0	22.8	24.0	1.85	3.68	16.8	52.1
Fenoxaprop-p-ethyl 60 g/ha	66.0	79.0	21.7	23.1	1.39	2.59	7.96	30.7
Fenoxaprop-p-ethyl + penoxsulam 60+26.7 g/ha	70.0	83.0	22.7	23.8	1.74	3.26	12.9	41.9
Cyhalofop + penoxsulam 135+26.7 g/ha	69.3	82.3	22.5	23.7	1.64	2.96	10.8	35.7
Bispyribac sodium + metsulfuon methyl + chlorimuron ethyl 25+4 g/ha	68.0	81.0	22.0	23.3	1.42	2.76	7.30	32.7
Triafamone + ethoxysulfuron 40+20 g/ha	69.0	82.0	22.2	23.4	1.49	2.87	7.67	33.5
Hand weeding	73.0	86.0	23.0	24.2	2.08	4.11	11.2	49.8
Weedy check	64.0	77.0	20.8	22.0	1.04	1.79	1.50	14.9
CD (P=0.05)	2.60		0.75		0.11		-	

RF= Rainfed, IR= Irrigated

maturation of the crop under rainfed rice. Irrigated rice had water application, and sufficient moisture in this way had maximum levels of yield attributing traits and grain yield. Among treatments, minimum yield attributing characteristics and grain production were observed in weedy check plot due to intense weed competition creating a limited supply of growth resources, while the maximum was recorded in hand weeding treatment because of less weed density and dry weight; there was no competition with the base crop and resulting in better growth and development of yield. Bispyribac sodium 25 g/ha, on the other hand, was found substantially superior over the remaining herbicides, with a higher no. of grains present per panicle (84.0), weight per 1000 seeds (24.0 g), and grain production (3.68 t), followed by fenoxaprop-p-ethyl + penoxsulam 60 + 26.7 g/ha (Kaur *et al*., 2016; Vivek *et al*., 2018).

Correlation analysis

A correlation analysis was conducted to examine the relationship between various factors in rainfed and irrigated rice, including plant height, plant biomass, test weight and grain yield. This analysis was further illustrated in fugures 3 to 6, providing visual representation of the results.

Economics

The net monetary return (NMR) was higher in irrigated agroecosystems than in rainfed agroecosystems (Table 4). In the case of weed control treatments, NMR was observed to be lowest and improved with usage of bispyribac sodium 25

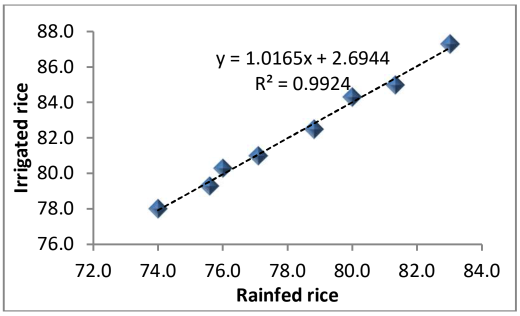

Figure 3. Relationship between plant height of rainfed and irrigated rice

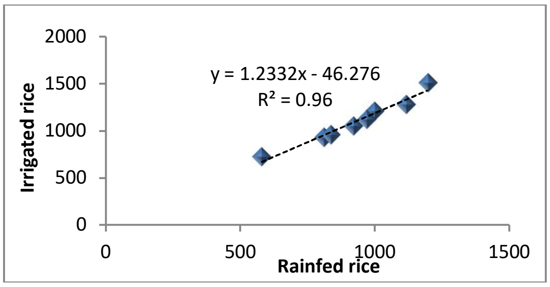

Figure 4. Relationship between plant biomass of rainfed and irrigated rice

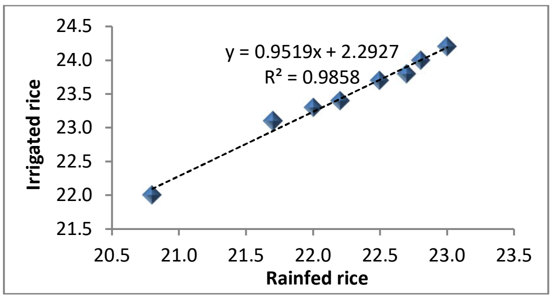

Figure 5. Relationship between 1000-seed weight of rainfed and irrigated rice

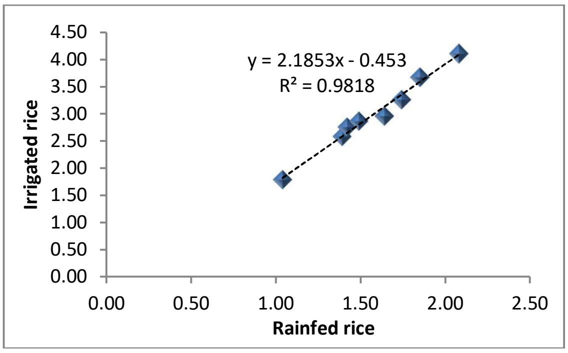

Figure 6. Relationship between grain yield of rainfed and irrigated rice

g/ha treatment (Rs.52123/ha) accompanied by fenoxaprop-p-ethyl + penoxsulam 60 + 26.7 g/ha. According to Prashanth *et al*. (2016) the treatment that generated the highest net return, was the treatment of 25 g/ha of bispyribac sodium. The lowest net monetary returns, however, were produced by unweeded checks

Conclusion

Weeds are the leading problem creators in direct seeded rice production. The control of weeds, therefore, becomes necessary through an appropriate combination of herbicides. The application of bispyribac sodium 25g/ha significantly reduced weed density and dry weight due to its broad-spectrum control of weed flora during the critical period. A higher yield was observed under the treatment of bispyribac sodium 25g/ha. The lesser weed competition resulted in better vegetative and reproductive growth, contributing to a greater number of tillers and, ultimately, a higher yield. Thus, the farmers can adopt the post-emergence application of bispyribac sodium 25g/ha as a wise option to control weeds in direct seeded rice under rainfed and irrigated agroecosystems.

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Conflict of interest

The authors declare that they have no conflict of interest.

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