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Chemical Control Against Aggressive Broad Leaves Weed Ipomea sp. in Drill Seeded-rice (*Oryza sativa L.*)

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Authors' contributions

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

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ABSTRACT

Two field experiments were carried out at the Experimental Farm of Rice Department, Sakha Agricultural Research Station, Kafrelsheikh, Egypt throughout 2020 and 2021 summer seasons to identify an efficient chemical control program against Ipomea sp. as perennial Convolvulaceae weed in drill seeded-rice. The experimental design was split-plot with three replications. Three times of herbicidal application at 20, 30 and 40 days after sowing (DAS) were allocated randomly in main plots, while in sub-plots, six weed control treatments were randomly distributed included three single herbicides application (bentazone at rate of 1.714 kg ai ha-1, fluroxypyr at rate of 0.0952 kg ai ha-1 and bensulfuron-methyl at rate of 0.0714 kg ai ha^{-1}) in addition to two herbicide mixtures were bentazone + fluroxypyr (1.344 kg ai ha-1 + 0.0952 kg ai ha^{-1}) and bensulfuron + fluroxypyr (0.0714 kg ai ha-1 + 0.0952 kg ai ha^{-1}) as compared to un-treated (weedy check) plots. Chemical control at early stage (20 DAS) achieved the best Ipomea control and recorded the lowest values of tillers number m-2, fresh and dry weights during 2020 and 2021, consequently recorded the highest rice dry matter, panicles number m-2, panicle weight and grain yield during both seasons. The results also showed that herbicide mixtures exceeded single application of herbicide in controlling Ipomea

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as broad leaf weed, bentazon + fluroxypyr ranked first in weed control efficiency percentage and recorded the lowest weed density m-2, fresh and dry weights of Ipomea during the two seasons of study as well as achieved the best values in rice dry matter, panicles per square meter, panicle weight and grain yield during 2020 and 2021 seasons, while the mixture of bensulfuron + fluroxypyr ranked second in this respect. The combination of bentazone + fluroxypyr sprayed at 20 DAS recorded the best Ipomea chemical control efficiency (95.4 %) and recorded the best rice grain yield (9.322 t ha-1) as an average for Giza 178 cv under drill seeded-rice conditions.

Keywords: Rice; Ipomea spp.; weed; time of application; and chemical control.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the main food crop in many countries in Africa and Asia. In Egypt rice is a main dish for most of population, it is play many important social, agricultural and economic roles in the Egyptian society. Rice is considered a source of protein, carbohydrates, minerals and vitamins. Rice cultivation protects soil in the salt belt beside Mediterranean Sea from salt desertification by sea water, moreover save Egyptian food security beside wheat crop. Cultivated area by rice in Egypt was 474,494 ha which produced 4,841,327 tons of paddy rice [1].

Weeds is the main threat in rice production, it compete with rice plants on water light, space and nutrients. Baltaz and De Datta [2] reported that more than one thousand weed spices attack rice fields worldwide. Weeds can cause yield reduction ranged from 28 to 100% depending on planting method, water regime and weed flora in the cultivated zone [3]. In Egypt, Abd El-Naby and El-Ghandor [4] found that weeds caused 93% yield reduction in direct seeded-rice.

At the beginning of the second millennium, rice cultivation system in Egypt was changed relatively from transplanted rice (flooding conditions) to direct seeding (aerobic conditions) and the occupied area by direct seeding was increased year after year which resulted in more challenges for rice crop. New, aggressive and various weed spices were appeared in rice fields such as broad leaf weeds (*Portulaca oleraceae, Xanthium sponisum, Convolvulus arvensis* and *Ipomea spp*.). Direct seeding of rice under aerobic conditions encourage the appearance of various and more weeds as compared to other rice planting methods [5]. Weeds can caused yield losses reach up to 91% [6].

Ipomea spp. (morning glory) as Convolvulaceae weed is climbing rice crop and cover it then make as a carpet above rice plants and obstruct sun light penetration to rice vegetative canopy then reduced photosynthesis which cause weakness in rice growth and decrease rice yield, difficulties in mechanized harvest of rice and increase moisture content in rice seeds which encourage many fungus and bacteria to grow and destroy rice seeds especially under seed production system, moreover produce a huge number of big size seeds which make a problem in rice seed production because of hardness in separation weed seeds from rice seeds and spread weed infestation to another clean area.

Chemical control against *Ipomea spp*. in rice started at 1986 when applied thiobencarb as post-emergence herbicide or butachlor as pre-emergence herbicide [7]. Ritoine *et al*. [8] at Tanzania found that bentazone + propanil achieved the best weed control than butachlor, bensulfuron and hand weeding. Pier [9] reported that 2,4-D is effective in *Ipomea* control but still need more research. The mixture of bensulfuron + bispyribac-sodium 60% WG at rate of 100 $g.acre^{-1}$ recorded about 58% control of *Ipomea aquatica* in rice fields [10]. In Egypt, no herbicides were registered for chemical control against this weed in rice production system until now, so the main objective of this study is to test and evaluate broad leaf weeds herbicides registered in rice individually or as mixtures to reset a strong chemical weed against broadleaves generally and *Ipomea spp.* especially in rice fields.

2. MATERIALS AND METHODS

Two field trails were investigated at the Experimental Farm of Rice Research and Training Center (RRTC), Sakha, Kafrelsheikh, FCRI, ARC, Egypt, during summer seasons of 2020 and 2021 to put an effective chemical control program against *Ipomea* sp. weed in drill-seeded rice (Giza 178 cv). The experimental design was Randomized Complete Block Design (RCBD) in three replications.

Table 1. Tested herbicides trade name, active ingredient, rate Kg ai ha^{-1}, chemical group, molecular formula, site of action and target weeds

Herbicide trade name	Active ingredient (ai)	Rate (Kg ai ha^{-1})	Chemical group	Molecular formula	Site of Action	Target weeds
Basagran 48% AS	Bentazone	1.714	Benzothiadiazinone	$C_{10}H_{12}N_2O_3S$	Inhibition of photosynthesis - contact	broad leaf weeds + sedges
Starin 20% EC	Fluroxypyr-meptyl	0.0952	Pyridinecarboxylic acid	$C_{15}H_{21}Cl_2FN_2O_3$	Synthetic auxin - systemic	broad leaf weeds + woody brush
Reto 60% WG	Bensulfuron-methyl	0.0714	Pyrimidinylsulfonylurea	$C_{16}H_{18}N_4O_7S$	ALS inhibitors - Systemic	broad leaf weeds + sedges

Lit. = litter, ha = hectare (10000 m2), g = gram and ALS = acetolactate synthase

Sowing date was 13 and 22 May during 2020 and 2021, respectively. Experimental site was artificially infested by *Ipomea* seeds at rate of 100 seeds m^{-2} before drilling directly in the two seasons of study and the other weeds were removed manually every week starting from three weeks after sowing. Plot size was 20 m^2 (2 x 10 m). All agricultural practices were done as recommended for drill-seeded rice according to RRTC [11].

3. STUDIED FACTORS

3.1 A Time of Herbicidal Application

Three times of application were evaluated as follow:

1- Early application at 20 days from sowing (DAS).

2- Intermediate time of application at 30 DAS.

3- Late application at 40 DAS.

3.2 Weed Control Treatments

Five chemical weed control treatments were tested as compared to weedy check (un-treated) plots. Weed control treatments were as follow:

1- Basagran 48% AS (bentazone) at recommended dose (1.714 kg ai ha^{-1}).

2- Starin 20% EC (fluroxypyr-methyl) at rate of (0.0952 kg ai ha^{-1}).

3- Reto 60% WG (bensulfuron-methyl) at recommended dose (0.0714 kg ai ha-1).

4- Mixture of bentazone (1.344 kg ai ha^{-1}) + fluroxypyr at rate 0.0952 kg ai ha^{-1}.

5- Mixture of bensulfuron (0.0714 kg ai ha^{-1}) + fluroxypyr at rate 0.0952 kg ai ha^{-1}.

6- Weedy check (untreated).

All chemical treatments were applied in 300 liter water per hectare on wet land by using Knapsack sprayer then the soil was irrigated after the application by 24 hours and let the field to dry normally.

4. STUDIED CHARACTERISTICS

4.1 Weed Traits

At 70 days after seeding, *Ipomea* weed was sampled by area of 50 x 50 cm quadrate replicated four times for each plot, then counted, air dried then oven dried at 70 °C for 48 hours or to stable weight then dry weight as g m^{-2} for the weed was recorded during the two seasons. Studied traits were determined as follow:

1- Number of tiller m^{-2}.

2- Fresh weight g.m^{-2}.

3- Dry weight g.m^{-2}.

4- Weed control efficiency percentage (WCE %) according to Drost and Moody [12].

4.2 Rice Characteristics

1- Dry weight of rice (g m^{-2}): At 70 DAS by the same way for weed sampling

2- Number of panicles m^{-2}: before harvest, rice panicles were counted by area of 50 x 50 cm quadrate replicated four times then the main was calculated and attributed to number of panicles m^{-2}.

3- Panicle weight (g): ten rice panicles were sampled to determine panicle weight as average.

4- Grain yield (t ha^{-1}): at harvest the central four square meters from each plot were harvested and grain yield was estimated at 14% moisture content and converted to (t ha^{-1}).

5. STATISTICAL ANALYSIS

The collected data were subjected to proper statistical analysis of variance according to Snedecor and Cochran [13]. Weed data were statistically analyzed by MSTATC program after transformed according to square-root transformation ($\sqrt{[x + 0.5]}$), while rice collected data were directly analyzed by MSTATC program then the means of both weeds and rice characters were compared by using Duncan´s Multiple Range Test [14].

6. RESULTS AND DISCUSSION

6.1 *Ipomea* Weed Studied Parameters

6.1.1 Effect of studied factors

Data on number of tillers m^{-2}, fresh and dry weights g.m^{-2} as well as weed control efficiency percentage (WCE %) as influenced by the time of herbicidal application and weed control treatments are presented in Table 2. It could be observed that all abovementioned weed characteristics were highly significantly affected by the time of herbicidal application during 2020 and 2021 seasons. The early time of herbicidal application (at 20 days after seeding) achieved the highest reduction in number of *Ipomea* tillers, fresh and dry matter during both seasons of study. On contrast, the late time of herbicidal application (at 40 days after seeding) produced the largest values of weed number of tillers, fresh and dry weights per square meter in both seasons. In addition, the intermediate time of herbicidal application (at 30 days after seeding) recorded intermediate values for studied traits during both seasons of study.

The high efficiency of early time of herbicidal application may be referred to early seedling age of such weed consequently enhanced more success in controlling *Ipomea* as a broad leaf weed. Weeds must be controlled during critical period of weed competition to achieve high efficiency weed control and avoid more yield reduction [15].

Data in Table 2 revealed that weed number of tillers m^{-2}, fresh and dry weights $g.m^{-2}$ in addition to WCE % exhibited highly significant response to weed control treatments in 2020 and 2021 seasons. Chemical weed control contained single herbicides or herbicides mixtures achieved lower values of studied traits of *Ipomea* sp than weedy check plots during the study. It is obvious from the data that mixture of bentazone + fluroxypyr or mixture of bensulfuron + fluroxypyr significantly surpassed single application of all tested herbicides in the reduction of number of tillers, fresh and dry weights of the weed during both seasons of study. Additionally the application of herbicides mixtures achieved the highest weed control efficiency against *Ipomea* weed throughout the two seasons of study. The high efficiency of herbicides mixtures in controlling *Ipomea* sp reflect the high effectiveness of the two different active ingredients in the mixture on inhibiting the bioactivities of such aggressive weed than the application of one active ingredient. The mixture of bentazone + propanil at rate of 4 and 5 kg ai ha^{-1} recorded the best *Ipomea* weed control and surpassed single application of butachlor or Molinate [8]. These results are confirmed with those obtained by **Soomoro and Soomoro** [10].

6.1.2 Effect of the interaction on weed parameters

Data in Table 3 shows fresh weight of *Ipomea* sp weed as affected by the interaction between time of herbicidal application and weed control treatments during 2020 and 2021 seasons. Fresh weight of the weed significantly decreased under the earlier application of single or mixed herbicides. The lowest fresh weight value of *Ipomea* sp was observed in plots treated by the mixture of bentazon + fluroxypyr at 20 days after sowing (DAS) followed by the application of bensulfuron + fluroxypyr at the same time of application in 2020 and 2021 seasons. On the other hand, the highest fresh weight value of the weed was obtained in weedy check plots. The significant reduction in *Ipomea* fresh weight under earlier application of herbicides mixtures may be due to high ability of two active ingredients in suppressing growth and eliminating the young weed seedlings in such early stage [3, 15].

Based on data in Table 3, dry weight (g m^{-2}) of *Ipomea* weed was significantly reduced under the earliest application of herbicide mixtures by plots treated by the mixture of bentazone + fluroxypyr at 20 DAS followed by the application of bensulfuron + fluroxypyr at the same time of herbicidal application at the same level of significance during 2020 and 2021 seasons. While the highest dry weed biomass was achieved by weedy check plots under the late time of application during both seasons. The high reduction in weed dry matter under the earliest time of herbicidal application may be related to the severe depression in dry matter accumulation due to the inhibition of different biological processes as a result of high killing ability of two different active ingredients contained in herbicides mixtures. Avudaithai and Veerabadran [16] found that the application of two different herbicides as a mixture at reduced doses proved high effective against many weed spices.

6.2 Rice Crop Characteristics

6.2.1 The main effect

Dry weight of rice, number of panicles m-2, panicle weight and grain yield mean values as influenced by the time of herbicidal application and weed control treatments against Ipomea weed are presented in Table 4. Based on the recorded data, the highest values of all previously mentioned traits were produced from plots treated at the earliest time of application (20 DAS), while the lowest values of rice studied characteristics were obtained when applied weed control treatments at late time (40 DAS).

Table 2. Number of tillers m^{-2}, fresh and dry weights ($g\ m^{-2}$) and weed control efficiency (%) of *Ipomea* sp weed as affected by time of herbicidal application and weed control treatments during 2020 and 2021 seasons

Factor	Number of tillers m^{-2}		Fresh weight ($g\ m^{-2}$)		Dry weight ($g\ m^{-2}$)		WCE (%)	
	2020	**2021**	**2020**	**2021**	**2020**	**2021**	**2020**	**2021**
Time of application (DAS)								
at 20 days	83.6 (8.5 c)	60.4 (6.8 c)	391.4 (16.1 c)	331.5 (14.1 c)	53.4 (6.1 c)	46.9 (5.6 c)	-	-
at 30 days	96.9 (9.2 b)	79.1 (8.1 b)	446.4 (17.6 b)	384.0 (15.6 b)	74.9 (7.7 b)	65.3 (6.9 b)	-	-
at 40 days	125.3 (10.9 a)	103.1 (9.5 a)	571.4 (21.3 a)	491.6 (19.9 a)	92.6 (9.1 a)	84.1 (8.5 a)	-	-
F. test	**	**	**	**	**	**	-	-
Weed control treatment								
Bentazone 48% LS	87.1 (9.2 c)	62.2 (7.7 c)	218.0 (14.4 d)	183.3 (13.4 c)	44.0 (6.4d)	37.3 (5.9 d)	79.8	81.5
Fluroxypyr 20% EC	101.3 (10.1c)	74.7 (8.5 c)	261.3 (15.8 c)	211.1 (14.3 c)	55.7 (7.3 c)	48.0 (6.8 c)	74.4	76.2
Bensulfuron 60% WG	126.2 (11.2b)	112.0 (10.4 b)	459.2 (21.1 b)	392.6 (19.5 b)	91.5 (9.5 b)	85.4 (9.1 b)	57.9	57.6
Bentazone + fluroxypyr	33.8 (5.6 d)	14.2 (3.3 e)	62.6 (7.8 f)	40.0 (5.2 e)	11.9 (3.3 f)	7.5 (2.6 f)	94.5	96.3
Bensulfuron + fluroxypyr	44.4 (6.5 d)	26.7 (5.1 d)	91.3 (9.5 e)	80.7 (8.1 d)	21.3 (4.4 e)	13.1 (3.3 e)	90.2	93.5
Weedy check	218.7 (14.8 a)	195.6 (14.0 a)	1725.8 (41.5 a)	1506.6 (38.8 a)	217.3 (14.8 a)	201.3 (14.2 a)	0.0	0.0
F. test:	**	**	**	**	**	**	--	--

*** indicates $P < 0.01$. Transformed values are shown in parentheses. In a column, means of transformed data followed by the same letter are not significantly different at 5% level, using Duncan's Multiple Range Test. DAS = days after sowing*

Table 3. Effect of interaction between time of herbicidal application and weed control treatments on fresh and dry weights (g m^{-2}) of *Ipomea* sp during 2020 and 2021 seasons

Weed control treatment	**Time of application**					
	20 DAS	**30 DAS**	**40 DAS**	**20 DAS**	**30 DAS**	**40 DAS**
	***Ipomea* fresh weight (g m^{-2})**					
	2020			**2021**		
Bentazone 48% AS	132.3 (11.5 fg)	161.6 (12.7 ef)	360.2 (18.9 cd)	125.1 (11.2 fg)	172.9 (13.2 ef)	251.9 (15.8 de)
Fluroxypyr 20% EC	153.1 (12.4 ef)	209.1 (14.5 e)	421.7 (20.5 c)	139.4 (11.8 fg)	181.4 (13.5 ef)	312.4 (17.7 cd)
Bensulfuron 60% WG	288.0 (17.0 d)	416.3 (20.4 c)	673.4 (25.9 b)	242.1 (15.5 de)	365.4 (19.1 c)	570.4 (23.9 b)
Bentazone + Fluroxypyr	45.3 (6.8 j)	49.6 (6.9 j)	93.0 (9.6 ghi)	13.4 (2.6 i)	14.5 (3.4 hi)	92.0 (9.6 g)
Bensulfuron + Fluroxypyr	64.5 (8.0 ij)	84.4 (9.2 hi)	124.9 (11.2 fgh)	28.2 (5.4 h)	33.3 (5.6 h)	180.5 (13.2 ef)
Weedy check	1664.7 (40.8 a)	1757.4 (41.9 a)	1755.3 (41.8 a)	1440.9 (37.9 a)	1536.4 (39.2 a)	1542.6 (39.3 a)
Weed control treatment	***Ipomea* dry weight (g m^{-2})**					
	2020			**2021**		
Bentazone 48% AS	18.1 (4.3 hi)	49.3 (6.9 f)	64.6 (8.1 de)	14.6 (3.9 i)	40.9 (6.3 fg)	56.3 (7.5 de)
Fluroxypyr 20% EC	28.5 (5.4 g)	62.5 (7.9 de)	76.2 (8.7 d)	21.8 (4.7 hi)	54.2 (7.4 def)	67.9 (8.3 d)
Bensulfuron 60% WG	53.1 (7.3 ef)	95.93 (9.8 c)	125.6 (11.2 b)	47.7 (6.9 ef)	87.6 (9.4 c)	120.8 (11.1 b)
Bentazone + Fluroxypyr	5.6 (2.5 k)	6.1 (2.6 k)	23.9 (4.9 gh)	2.8 (1.8 j)	4.1 (2.2 j)	15.5 (3.9 i)
Bensulfuron + Fluroxypyr	9.6 (3.1 jk)	13.9 (3.8 jk)	40.6 (6.4 f)	4.7 (2.2 j)	5.6 (2.4 j)	28.9 (5.4 gh)
Weedy check	205.3 (14.3 a)	221.6 (14.9 a)	225.0 (15.1 a)	189.5 (13.8 a)	199.4 (14.1 a)	215.1 (14.7 a)

Means fb a common letter within a season are not significantly differed at 5% level, using DMRT. Values within parentheses are transformed

Fig. 1. Rice growth in plots treated with bentazon + fluroxypyr as compared to weedy check plots under study conditions

Whereas under herbicidal application after 30 DAS produced the intermediate values of all abovementioned characteristics. The increase in dry weight, number of panicle per unit area, panicle weight and grain yield of rice under the earliest time of herbicidal application reflect the high efficacy of weed control treatments under such time of application which enhanced more dry matter accumulation, more panicles, heaviest panicles consequently improve grain yield of rice during the two seasons of study. Rahman *et al*. [17] reported that tank mixture of cyhalofop-P-butyl and bensulfuron methyl resulted in high effective broad spectrum control against grass, sedges, and broad leaf weeds.

Data in Table 4 revealed that dry weight, number of panicles m^{-2}, panicle weight and grain yield of rice were greatly affected by weed control treatments during both seasons of study. The values of all mentioned characteristics under bentazone + fluroxypyr mixture were significantly superior to all other treatments followed by those obtained from rice plots treated with bensulfuron + fluroxypyr mixture and bentazon alone. The lowest figures of all abovementioned traits were observed in un-treated plots. The same trends were observed in the two seasons of study. The superiority of herbicide mixtures in increasing rice dry matter, panicles m^{-2}, panicle weight and grain yield of rice may be due to the high efficient chemical control against weeds in the presence of more than one active ingredient with different mode of action which give optimum chance for rice plants to use the available moisture, sun light, space and nutrients resulted in positive growth and produce high grain yield of rice. These findings are in harmony with those reported by many researchers in their studies [18,19,20].

6.2.2 The interaction effect on rice studied characteristics

Data in Table 5 showed the significant effect of interaction between the time of herbicidal application and weed control treatments on rice dry weight, number of panicles m^{-2} and grain yield during 2020 and 2021 seasons. As shown in this table, dry weight of rice plants (g m^{-2}) was greatly influenced by the interaction. The highest values of rice dry matter were recorded with the application of mixture of bentazone + fluroxypyr at 20 DAS followed by bensulfuron + fluroxypyr applied at the same time of application. Additionally, the application of bentazone + fluroxypyr at 20 or 30 DAS achieved the heaviest dry weights of rice plants with no significant differences. On the other hand, the late application of single herbicides showed significant inferiority in dry weight of rice plants, while the lowest dry weigh of rice was obtained from un-treated plots at latest time of application. The same trends were true in 2020 and 2021 seasons. The increment of rice dry weight under both herbicide mixtures applied at 20 DAS explain the high effectiveness of such treatments in controlling *Ipomea* weed as a broad leaf weed during early growth stage consequently enhance the available water, light and nutrients for rice plants to accumulate more dry matter, panicles and grain yield. These results are similar to those observed by many researchers in their studies [19,21].

Table 4. Effect of time of herbicidal application and weed control treatment on rice dry weight (g m^{-2}), number of panicles m^{-2}, panicle weight (g) and grain yield (t ha^{-1}) during 2020 and 2021 seasons

Factors:	Rice dry weight (g m^{-2})		Rice panicles m^{-2}		Panicle weight (g)		Grain Yield (t ha^{-1})	
	2020	2021	2020	2021	2020	2021	2020	2021
Time of application (DAS)								
at 20 days	761.1 a	838.8 a	364.4 a	390.2	1.5 a	1.6 a	6.744 a	7.026 a
at 30 days	672.6 b	774.8 b	342.2 b	366.2	1.3 b	1.4 b	6.399 a	6.644 a
at 40 days	505.9 c	620.7 c	284.4 c	308.4	1.1 c	1.1 c	4.654 b	4.895 b
F. test	**	**	**	**	**	**	**	**
Weed control treatment								
Bentazone 48% LS	710.4 c	796.6 c	368.0 c	389.3 c	1.4 bc	1.5 bc	6.482 c	6.953 c
Fluroxypyr 20% EC	632.9 d	736.3 d	344.9 d	366.2 d	1.3 c	1.4 c	5.965 d	6.279 d
Bensulfuron 60% WG	503.4 e	624.1 e	273.8 e	305.8 e	1.1 d	1.2 d	5.388 e	5.722 e
Bentazone + Fluroxypyr	989.5 a	1126.8 a	458.7 a	481.8 a	1.8 a	1.9 a	9.324 a	9.320 a
Bensulfuron + Fluroxypyr	871.8 b	982.6 b	428.4 b	458.7 b	1.5 b	1.6 b	8.042 b	8.314 b
Weedy check	171.1 f	202.3 f	108.4 f	128.0 f	0.5 e	0.6 e	0.392 f	0.542 f
F. test:	**	**	**	**	**	**	**	**

*** indicates P< 0.01. Means of each factor within each column, values fb the same letters are not significantly differed at 5% level, using DMRT. DAS = days after sowing*

Table 5. Effect of interaction between time of herbicidal application and weed control treatment on rice dry weight (g m^{-2}), panicle weight (g), number of panicles m^{-2} and grain yield (t ha^{-1}) during 2020 and 2021 seasons

Weed control treatment	Time of application (DAS)					
	at 20 days	at 30 days	at 40 days	at 20 days	at 30 days	at 40 days
	Rice dry weight (gm^{-2})					
	2020			2021		
Bentazone 48% LS	848.1 cd	731.4 de	551.7 f	922.5 cd	787.8 ef	679.4 gh
Fluroxypyr 20% EC	762.6 de	692.4 e	443.8 fg	849.7 de	746.5 fg	612.7 h
Bensulfuron 60% WG	676.9 e	464.3 fg	368.9 g	708.8 fg	670.1 gh	493.4 i
Bentazone + Fluroxypyr	1127.7 a	1048.6 ab	792.2 de	1237.5 a	1197.3 a	945.7 c
Bensulfuron + Fluroxypyr	975.8 b	935.7 bc	704.0 e	1105.5 b	1038.2 b	804.3 ef
Weedy check	175.4 h	163.4 h	174.5 h	209. 1 j	208.8 j	188.9 j
Weed control treatment	Number of panicle m^{-2}					
	2020			2021		
Bentazone 48% LS	400.0 b	373.3 bcd	330.7 ef	421.3 b	394.7 bc	352.0 de
Fluroxypyr 20% EC	384.0 bcd	352.cbe	298.7 fg	405.3 bc	373.3 cd	320.0 ef
Bensulfuron 60% WG	314.7 ef	266.7 gh	240.0 h	346.7 de	298.7 fg	272.0 g
Bentazone + Fluroxypyr	501.3 a	485.3 a	389.3 bc	528.0 a	506.7 a	410.7 bc
Bensulfuron + Fluroxypyr	469.3 a	469.3 a	346.7 de	501.3 a	496.0 a	378.7 cd
Weedy check	117.3 i	106.7 i	101.3 i	138.7 h	128.0 h	117.3 h
Weed control treatment	Panicle weight (g)					
	2020			2021		
Bentazone 48% LS	1.8 ab	1.4 de	1.0 fg	1.9 bc	1.4 efg	1.2 ghi
Fluroxypyr 20% EC	1.7 bc	1.2 d-g	0.9 g	1.8 bcd	1.3 gh	1.0 i
Bensulfuron 60% WG	1.2 d-g	1.1 efg	0.9 g	1.3 fgh	1.2 ghi	1.1 hi
Bentazone + Fluroxypyr	2.0 a	1.8 ab	1.5 cd	2.2 a	2.1 ab	1.6 def
Bensulfuron + Fluroxypyr	1.8 ab	1.5 cd	1.3 def	1.9 bc	1.6 cde	1.4 efg
Weedy check	0.5 h	0.5 h	0.4 h	0.7 j	0.6 j	0.5 j
Weed control treatment	Grain yield (t ha^{-1})					
	2020			2021		
Bentazone 48% LS	7.515.de	7.048 ef	4.884 h	8.015 de	7.644 def	5.199 h
Fluroxypyr 20% EC	7.067 ef	6.772 f	4.58 i	7.445 ef	7.036 f	4.356 i
Bensulfuron 60% WG	6.545 fg	5.971 g	3.649 i	7.084 f	6.205 g	3.877 i
Bentazone + Fluroxypyr	10.037 a	9.978 a	7.958 cd	10.037 a	9.672 a	8.252 cd
Bensulfuron + Fluroxypyr	8.837 b	8.263 bc	7.026 ef	9.022 b	8.760 bc	7.160 f
Weedy check	0.464 j	0.362 j	0.349 j	0.553 j	0.549 j	0.525 j

Means fb a common letter within a season are not significantly differed at 5% level, using DMRT. Values within parentheses are transformed. DAS = days after sowing

As shown in Table 5, number of panicles m^{-2} of rice was considerably affected by the interaction of time of herbicidal application x weed control treatments in the two seasons of study. The highest values of rice panicles m^{-2} and panicle weight (g) was obtained from plots treated with the mixture of bentazone + fluroxypyr or bensulfuron + fluroxypyr at 20 DAS at the same level of significance. Whereas, number of panicles m^{-2} and panicle weight were inferior under the application of single herbicides at the late time of herbicidal application. On the other hand, weedy check plots produced the lowest values of rice panicles per unit area and panicle weight. The same trend trends of results were noted during 2020 and 2021 seasons. The higher number of panicles and panicle weight under early time of herbicide mixtures application (20 DAS) may reflect the high effectiveness of *Ipomea* control and the better dry weight accumulation of rice plants. It could be observed from data in Table 5 that grain yield of rice was greatly influenced by the interaction between the two studied factors. Grain yield of rice was decreased by delaying the application time as well as single application of herbicides for *Ipomea* weed control. The application of herbicide mixtures at 20 DAS produced the highest grain yield, while bentazone + fluroxypyr mixture surpassed bensulfuron + fluroxypyr in this respect. Moreover, bentazone + fluroxypyr mixture treatment continue to produce higher grain yield of rice even under 30 DAS. On the other hand, the weedy check plots (un-treated) produced the lowest grain yield of rice than all treated plots. The same trend of results was clear through two seasons of study. The superiority of the early application of herbicides mixtures in grain yield may result from more dry weight accumulation by rice plants and more panicles per unit area due to the high effective *Ipomea* chemical control at early stage osf growth excluding this aggressive weed competition of this weed. Moreover, bentazone + fluroxypyr mixture yielded the best grain yield even when applied at 30 DAS. These results confirmed the stable high efficiency of this mixture in controlling *Ipomea* as Convolvulaceae broad leaf weed. These findings are confirmed with those reported by Ritoine et al. [8], Shad [7] and Soomoro and Soomoro [10].

7. CONCLUSION

To overcome the problem of *Ipomea* as an aggressive broad leaf weed in rice fields, herbicide mixtures must be used at early stage (20 DAS) in direct seeded-rice. The mixture of bentazone + fluroxypyr-methyl at rate of (1.344 kg ai ha^{-1} + 0.0952 kg ai ha^{-1}) was more efficient to control this weed and produce the best grain yield of rice.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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