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INTEGRATED WEEDS MANAGEMENT IN DRY-SEEDED BASMATI RICE

T. H. Awan[1], M. U. Saleem[1], S. Hussain[2], S. Ahmed[3] and H. H. Ali[4]

[1]Rice Research Institute, Kala Shah Kaku, Punjab, Pakistan; [2]Pakistan Agricultural Research Council, Rice Program, Kala Shah Kaku, Punjab, Pakistan; [3]International Rice Research Institute (IRRI), Bangladesh office .
[4]Department of Agronomy, College of Agriculture, University of Sargodha, Sargodha, Punjab, Pakistan.
Corresponding Author's email: tahirawanrri@gmail.com**,** t.awanuplb@gmail.com

ABSTRACT

The simultaneous emergence of rice and weed seedlings under alternate wetting and drying field conditions favors high weed infestation in dry-seeded rice (DSR) systems. Due to high weed pressure in DSR, a single weed management approach often provides sub-optimal weed control. Therefore, weed management in DSR systems demands an integrated approach. Field experiments for weed management in dry-seeded rice were conducted at Rice Research Institute, Kala Shah Kaku, Lahore, during 2010 and 2011. Weed control treatments i.e. bispyribac sodium, ethoxysulfuron, bispyribac sodium + hand weeding, ethoxysulfuron + hand weeding, single hand weeding, and double hand weeding were compared with the weedy check in a randomized complete block design. Results revealed that maximum weeds control (97.2%) was achieved in the double hand weeded plots and in the plots treated with bispyribac sodium + hand weeding (94.5%) during the first year. However, during the second-year maximum weed control (98.3%) was obtained in bispyribac sodium + hand weeded plots, which was at par with double hand weeding (93.5%) and ethoxysulfuron + hand weeding (93.0%). Bispyribac sodium + hand weeded plots produced a maximum number of tillers m^{-2} (338 and 297), the longest panicles (27 and 28.2 cm) with the maximum number of grains/panicle (116.3 and 121.8) during both years. The highest paddy yield (3.2-4.0 t ha^{-1}) was also obtained from the plots where bispyribac sodium + hand weeding was performed, whereas, lowest paddy yield (0.9-1.1 t ha^{-1}) was achieved in the nontreated plots. Results from the study concluded that integration of hand weeding with a post-emergence application of bispyribac sodium is the best weed management option in DSR for controlling weeds as well as higher paddy grain yield.

Keywords: Bispyribac sodium; ethoxysulfuron; herbicides; hand weeding; weed control efficiency; yield and yield components

INTRODUCTION

Rice (*Oryza sativa* L.) is the leading cereal crop in the world and second most important staple food of the people of Pakistan after wheat (Manzoor *et al.,* 2006). In Pakistan, the rice crop is grown on an area of 2.89 million hectares (ha), with annual production 7.44 million tons (t) and an average yield of 2.56 t ha^{-1} of clean rice, much lower than many other rice-growing nations of the world (Anonymous, 2014-15). Although, there is a great scope of increasing rice production, however, present yield level of existing rice cultivars is much lower than the potential of the varieties. Suboptimal plant densities due to manual transplanting in the hot season are one of the major causes of lower paddy yield. Despite the enormous efforts of crop specialists, media publicity, and farmers, farm labors could not transplant the required number of plants ha^{-1}. This issue compelled researchers to explore new ways of ensuring optimum plant population in the fields without scarifying the yield. Dry seeded rice (DSR) and mechanized transplanting are the alternative technologies in order to maintain the optimum plant density per unit area. The implementation of mechanized transplanting is very costly due to the high price of transplanter and requires a higher level of skilled workers. The only feasible option under local conditions left is to adopt DSR technology. Massive weeds infestation is, however, a major constraint in large-scale adoption of this technology (Chauhan *et al*., 2012).

Because of the simultaneous emergence of weeds and rice in DSR, weeds are more problematic in DSR than in transplanted rice systems. Weeds compete with the crop for moisture, nutrients, light, and space resulting in poor crop growth and require a higher level of input resources, especially nutrient and moisture (Ahmed *et al.,* 2015). In Pakistan, yield losses due to weeds in dry-seeded systems are recorded 27-80% (Awan *et al*., 2006a; Khaliq *et al*., 2012); however, in extreme cases, it results in complete crop failure up to 100% (Jabran *et al*., 2012). Hence, judicious weed management is crucial in attaining food security in developing countries of Asia (Chauhan *et al.,* 2012).

The most serious weeds in DSR in sub-continent are *Echinochloa colona, E. crus-galli*, *E. glabrescens*, *Cyperus rotundus*, *C. difformis*, *Cyperus iria*, *Cyperus maritimus*, *Paspalum distichum*, *Digitaria ciliaris*, *Eleusine indica*, *Marsilea minuta* (Ahmed *et al.,* 2014; Awan *et al.,* 2006b). These weeds are also problematic in the rice fields of Punjab Province, Pakistan (Awan *et al.,* 2006b).

Weeds in dry-seeded rice can be managed through several methods; however, manual and chemical methods are most commonly practiced. Manual weeding is very common in South Asian countries, but nowdays it is not an economical and feasible option because of labor scarcity and their high wages (Mann *et al*., 2007). In the current scenario, the only feasible and economical method of weeds control in rice is the use of chemicals. Chemical weed control using herbicides saves time and labor (Mazid *et al*., 2003). Several pre- and post-emergence herbicides have been reported for effective weed control in DSR, however, many studies reported that pre-emergence herbicide must be applied to stop the simultaneous emergence of weeds. Pre-emergence herbicides need to be applied in soil but in Pakistan farmers usually, don't practice this.

Pre-emergence herbicides (oxadiazon, pendimethalin, etc) are usually applied within 3 days after sowing (DAS) of rice, preferably immediately after planting and before the emergence of weeds and crops (Ahmed and Chauhan, 2014). These herbicides are usually cell division inhibitors and are no longer effective beyond the first leaf stage. Early post-emergence herbicides (e.g., butachlor, propanil, thiobencarb, etc) are applied at the 2–4 leaf stages. Late post-emergence herbicides (e.g., bispyribac-sodium, azimsulfuron, fenoxaprop, ethoxysulfuron, 2,4-D, etc) are usually applied on foliar and the application time ranges from 14–28 DAS (Awan *et al*., 2015).

The major rice establishment system in Pakistan is transplanted rice where a farmer uses early post-emergence herbicides which require standing water in the field for 5-7 days after their use but it is not possible in the DSR systems. In DSR, weeds began to emerge simultaneously with rice seedlings and farmers do not try to control them by pre-emergence herbicides to avoid any phytotoxicity to rice seedlings (Hi-Jinhao *et al.,* 1999). Research showed that there is severe phytotoxicity to rice seedlings if there is rain or irrigation immediately after application of pre-emergence herbicides (Awan *et al* 2016). These weeds need to be controlled by using late-post emergence herbicides (Chauhan *et al*., 2015).

Since the DSR field gets infested by complex and diverse weed species, no one single herbicide is competent to control all weed species. Therefore, a combination of herbicide (sequential applications or tank mixtures) or a broad-spectrum herbicide along with other cultural practices is essential for effective control of all groups of weeds such as sedges, broadleaved, and grasses (Awan *et al*., 2015).

The continuous injudicious use of herbicides has effects on environmental pollution, especially water pollution (Rohr and Crumrine, 2005), human health, animals and marine life, risks to beneficial organisms (Das *et al*., 2003), adjacent crops (De Snoo and Der Poll, 1999); and the evolution of herbicides-resistant weeds. Currently, there are 403 documented cases (species by the site of action) of herbicide resistance among 218 weed species of 66 crops in 61 countries worldwide (Heap, 2013).

The negative effects of herbicide application to the environment may limit the use of herbicide options available for farmers in the future (Johnson and Mortimer, 2008). Therefore, there is a need to develop sustainable integrated weed management strategies, including diverse agronomic approaches to suppress weeds and minimize herbicide use.

The present study was therefore designed to evaluate the late-post-emergence herbicides alone and in combination with manual weeding to find out the most appropriate weed control method with less use of herbicides in controlling weeds of DSR.

MATERIALS AND METHODS

The study was conducted at Rice Research Institute, Kala Shah Kaku, Punjab, Pakistan (having latitude: 31.740655°, longitude: 74.253146°, and elevation: 207 m) during 2010 and 2011 to find out the most appropriate method of weed control in dry drill sown basmati rice. The physio-chemical properties of the experimental site are given in Table 1. In the experiment, six weed management treatments such as bispyribac sodium, bispyribac sodium + hand weeding, ethoxysulfuron, ethoxysulfuron + hand weeding, one hand weeding, two hands weeding, and control (weedy) were evaluated. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The individual plot size was 5 m x 10 m (50 m^2). Super Basmati was used as a test variety in this study for both years.

The field selected for this study was previously under rice-wheat cropping system from many years. The field was prepared in dry condition and sowing of the pre-soaked seed (24 hours plain water soaking) was done with a zero-tillage drill on June 5, 2010, and June 7, 2011. Seed drilling was done at a row spacing of 22.5 cm. Fertilizers were applied at the rate of 45-85-62 kg ha^{-1} of N-P-K in the form of urea, di-ammonium phosphate and potassium sulfate, respectively, at the time of sowing through zero-tillage drill machine. The N was top dressed at the rate of 45 kg ha^{-1} at 35 and 55 days after seeding. Herbicides (bispyribac sodium @ 30 g a.i. ha^{-1} and ethoxysulfuron @ 30 g a.i. ha^{-1}) were sprayed at 21 days after sowing (DAS) using a knapsack sprayer fitted with flat fan nozzles which delivered a spray solution at the rate of 320 L ha^{-1} at a spray pressure of 140 kPa. The first-hand weeding was done at 21 DAS and the second-hand weeding was done at 35 DAS. Granular cartape insecticide was applied in the last week of August in both years. Irrigations were applied whenever required to avoid water stress during the whole crop growth period.

Other agronomic and cultural practices were kept standard and uniform for all the treatments during both years.

Weed density was recorded before (20 DAS) and after treatment application (50 DAS). Three samples were collected randomly from each plot with an area of 1 m^2 (1 m x 1 m) and their average was recorded finally. Percentage weed control was computed by the differences of weeds density before and after treatment application.

At rice maturity stage, plant height of five randomly selected rice plants was recorded from the ground to the tip of the flag leave. Rice tillers and panicles m^{-2} were counted from each plot. After threshing and cleaning, the total grain weight was obtained and moisture content was measured using grain moister meter Riceter F505 (Kett Electric Laboratory Tokyo Japan). The filled and unfilled grains were separated, counted and calculated the number of grains panicle^{-1}. Randomly, 1000 grains were subsampled, counted and weighed. Rice grain yield was determined from a harvested area of 5 m^2. Harvesting and threshing were done manually in the month of October in both years. The moisture content of the three subsamples was measured. Grain yield was converted to t ha^{-1} at 14% moisture content.

Data were analyzed using analysis of variance (ANOVA). ANOVA results showed an interaction between year and treatments; therefore, the data were analyzed separately using STAR 3.0 V [International Rice Research Institute (IRRI), Philippines]. Treatment means were separated using the least significant difference (LSD) at the 5% level of significance (Steel *et al.,* 1996).

RESULTS AND DISCUSSION

Composition of Weed Flora. The study was conducted under a naturally occurring population of mixed weeds, dominated by grass and broadleaf weeds. There were 16 different weed species at the experimental site. Grass weed species evaluated viz junglerice [*Echinochloa colona* (L.) Link], Chinese sprangletop [*Leptochloa chinensis* (L.) Nees], goosegrass [*Eleusine indica* (L.) Gaertn.], barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], and knotgrass (*Paspalum distichum* L.). Broadleaf weed species were gooseweed (*Sphenoclea zeylanica* Gaertn.), eclipta [*Eclipta prostrata* (L.) L.], three lobe morning glory (*Ipomoea triloba* L.), swamp morning glory (*Ipomoea aquatica* Forsk.), dove weed (*Murdannia nudiflora* L.), and monochoria [*Monochoria vaginalis* (Burm. f.) Kunth]. Sedge species were small flower umbrella sedge (*Cyperus difformis* L.), purple nutgrass (*Cyperus rotundus* L.), rice flatsedge (*Cyperus iria* L.), alkali bulrush (*Scirpus maritimus* L.), and globe fringerush [*Fimbristylis miliacea* (L.) Vahl]. Although several weed species were present at the experimental site, however, the dominant weeds were four grass species (*E. crus-galli*, *E. glabrescens, E. colona* and *Eleusine indica.*), three broadleaf species (*Ipomoea aquatic, commelina diffusa*, and *Marsilea minuta*), and four sedge species (*C. rotundus*, *C. difformis*, *C. iria*, *C. maritimus*).

Weeds density and weed control efficiency: Similar weed densities were recorded from most of the treatments before herbicide application during 2010 and 2011 (Table 2). Weed density ranged 192-317 weeds m^{-2}. Weed control treatments decreased weed density significantly compared with the weedy treatment. After treatments application, the highest weed density (263 plants m^{-2}) was recorded from the weedy treatment and the lowest density (7.2 plants m^{-2}) was recorded from two times hand weeded plots (Table 2). Results of the present study confirmed findings of Hussain *et al*. (2008) who obtained maximum weed control from hand weeding. Similarly, Parasad *et al*. (2001) also reported the highest weed control efficiency in hand weeding treatment in transplanted rice. In addition, bispyribac-sodium was found more effective in controlling weeds as compared with the ethoxysulfuron when applied without integration with hand weeding. Integration of hand weeding with herbicides increased weed control efficiency, and almost similar weed control was observed from bispyribac-sodium and ethoxysulfuron application followed by single hand weeding. Double hand weeding improved weed control percentage over single hand weeding (Table 2).

All herbicide-treated and hand weeded plots had lower weeds population compared with the season-long weedy plots (Table 2). Although variable densities were observed in different treatments before herbicide application, yet the effect of treatments was obvious from reduced weed densities after treatment application, and from weed control percentage data (Table 2). The minimum weed density (4.4 m^{-2}) was recorded from bispyribac-sodium + hand weeded plots. Similarly, the maximum weed control efficiency (98.3%) was obtained from bispyribac-sodium + hand weeding. Weeds density increased by 10% in no-weeding plots at 50 DAS compared with weed density at 20 DAS, indicating the emergence of new weeds up to 50 DAS. These results are in agreement with those of Hussain *et al*. (2008) who obtained an increasing number of weeds from weedy check plots in rice due to new flushes of weeds especially broadleaf.

Among weed control treatments comparatively lower weed control percentage (73.4 and 77.3%) was exhibited by ethoxysulfuron during both years (Table 2). More than 90% weed control was attained in the plots applied with bispyribac-sodium (91.4% and 94.3%), bispyribac-sodium + hand weeding (94.5 and 98.3%), ethoxysulfuron + hand weeding, and double hand weeding (97.2% and 93.5%). The less weed control efficiency by ethoxysulfuron application was due to its ineffectiveness against grassy weeds which were dominant in DSR systems (Ahmed and Chauhan, 2014; Awan *et al*., 2015). On the other hand, bispyribac-sodium controlled a range of grass and broadleaf weeds. Hussain *et al.* (2008) also obtained above 90% weed control by the application of bispyribac-sodium (100 SC) in aerobic rice. Sole application of bispyribac-sodium demonstrated better results than single hand weeding and it was statistically at par with double hand weeding and its integration with single hand weeding. The results of the study provided bispyribac-sodium as an alternative to hand weeding.

Yield and yield attributes: All weed control treatments had a significantly higher number of tillers m^{-2} compared with the season-long weedy plots (Tables 3). The lowest rice tiller density (99.3 and 29.7 tiller m^{-2}) was observed from weedy plots in both years. However, the highest tillers density (338 and 297 tiller m^{-2}) was recorded from the plot treated with bispyribac-sodium + hand weeding. Aside from weedy plots (99.3 m^{-2}), the lowest tiller density was observed in the plots applied with ethoxysulfuron (89.7-281.7 tiller m^{-2}) only and it was due to uncontrolled weeds, especially grasses, in ethoxysulfuron treated plots that had a competition with rice plants for resources.

Integration of hand weeding with herbicides had similar panicle density as with sole herbicide treatment in 2010; however, herbicide followed by hand weeding had significantly higher panicles than sole herbicide treatment during the second year. Ethoxysulfuron produced a lower number of panicles in 2011, compared with 2010 and it was due to the reasons that this herbicide controlled sedges and broadleaf weeds effectively but not found effective against grasses. Sedges were dominant weeds in 2010 but in 2011 the grass density increased and it was due to grass weed seed spread from the previous season. During 2011, grass weeds may have affected the crop badly so resulting in less number of panicles in the treatment.

The results of the current study demonstrated that effective weed control helps in enhancing the number of panicle density, while weedy treatment failed to show similar numbers. Similar results were found by Sandeep *et al*. (2002) who recorded more number of panicles m^{-2} from weed-free plots. Awan *et al*. (2002) reported that manual weed control plots produced more tillers than the plots applied with acetochlor @ 250 mL ha^{-1} and command 3E @ 668 mL ha^{-1}.

Weed control treatments significantly affected the panicle length in both years of study (Table 3). The maximum panicle length (27 and 28.2 cm) was recorded in the plots treated with bispyribac-sodium + hand weeding followed by bispyribac-sodium alone (25.6 and 26.8 cm), and double hand weeding (25.2 and 26.4 cm). The minimum panicle length was recorded from weedy plots (18.2 and 19.4 cm) in both years (Table 3). The panicle length recorded in the plots applied with Ethoxysulfuron was lower than the plots applied with bispyribac-sodium. Short panicle length in the ethoxysulfuron treatment was due to uncontrolled weeds, especially grasses, as this herbicide can control sedges and broad leaves only and cannot control the grasses, which can suppress the growth of rice plants. The results of the present study are in conformity with those of Mann *et al*. (2007) who achieved also longer panicles from herbicide-treated and weed free plots compared with weedy check-in dry-seeded rice.

Weed control treatments increased number of grains per panicle significantly over the control/no weeding (Table 3). The highest numbers of grains (116 $panicle^{-1}$) were recorded in the plots treated with bispyribac-sodium + hand weeding and double hand weeding (104 $panicle^{-1}$) (Table 3). The lowest number of grains (54 $panicle^{-1}$) was recorded from season-long weedy plots which were significantly lower than the herbicide-treated or hand weeded plots in 2010. A possible reason for this difference was herbicide-treated and hand weeding plots had lower crop-weed competition resulting in optimum growth of rice plant which was higher in season-long weedy plots. The similar trend was observed in the year 2011. Prasad *et al*. (2001) reported the highest value for grains per panicle from manual weeding compared with weedy plots. Similarly, Tamilselvan and Budhar (2001) obtained a higher number of grains $panicle^{-1}$ by controlling weeds with 3 kg anilophos a.i. ha^{-1}.

All weed control treatments except ethoxysulfuron application enhanced 1000 grain weight significantly over no weeding during both years. The maximum 1000 grain weight (23.2 g) was recorded in the plots applied with bispyribac-sodium which was statistically at par with all other treatments except ethoxysulfuron application (20.1 g) and no weeding (19.4 g) in 2010 (Table 3). The higher 1000 grains weight in bispyribac-sodium and hand weeding plots were due to less weed competition which was higher in ethoxysulfuron and weedy plots. Sole application of ethoxysulfuron could not influence 1000 grain weight significantly compared with no weeding. Similar results were followed in 2011. Ashraf *et al*. (2006) obtained higher grain weight from herbicide treated plots than the weedy check. Sandeep *et al*. (2002) recorded higher 1000 grain weight by controlling weeds in rice compared with a weedy check.

Grain yield was significantly influenced by the weed control treatments and had always higher paddy yield than the season-long weedy plots (Table 3). Higher paddy yield (3.2 and 4.0 t ha^{-1}) was achieved in the plots treated with bispyribac-sodium + hand weeding and bispyribac-sodium alone (3.1 and 3.8 t ha^{-1}) in both the years. Grain yield was higher in 2011 as compared to 2010, the reason might be that rainfall in the rice-growing season (June to October) of 2011was 857 mm while in 2010 was only 583 mm

The plots applied with herbicide + hand weeding produced a relatively higher yield than the plots applied with sole herbicides and single hand weeding. The lowest paddy yield (0.9-1.1 t ha^{-1}) was recorded in the season-long weedy plots. Higher paddy yield in weed control treatments may be attributed to better weed control, more productive tillers, higher number of grains $panicle^{-1}$, and better 1000 grain weight. Rekha *et al*. (2003) reported increased paddy yields with the application of different herbicides. Weed-free plots produced higher paddy yield than weedy plots (Ahmad *et al*., 2014; Awan *et al.,* 2015). The results of the present studies confirmed the findings of the earlier work.

Bispyribac sodium alone provided similar weed control and yield increments as provided by bispyribac sodium + hand weeding and double hand weeding in dry-seeded rice. Hand weeding is a costly method hence the application of bispyribac sodium may be adopted to control common rice weeds in aerobic rice.

In summary, the highest net benefit can be achieved by using bispyribac sodium sole. If there is a second flush of weeds, one hand weeding can be used after bispyribac sodium application. Our study concluded that the use of herbicides is an efficient and cost-effective method for weed control in DSR. Hand weeding can be adopted in those areas where labor is easily available and inexpensive. When the herbicide selection is appropriate, treatments comprising sole herbicides require less cost but produce higher net benefits than manual weeding (Awan *et al.,* 2015).

The above ground biomass of weeds was inversely related to grain yield in both the years. In both the years, a negative linear correlation was found between weed biomass and rice grain yield (Figure-2). The results of our regression analysis revealed that every 1 g m^{-2} increase in weed biomass at 50 DAS resulted in a decrease of 7.7 kg in 2010 and 8.95 kg in 2011 of rice grain yield (Figure-2).

The current study suggests that various weed control options are available to control weeds economically in DSR systems. Mechanized DSR is a new system in Asia, including Pakistan, and the availability of different weed management options will help in promoting this system, as weeds are the main constraints in this system (Chauhan, 2012). Our study inferred that bispyribac sodium or ethoxysulfuon herbicides can control annual grasses, sedges, and broadleaf weed species. In this regard, post-emergence herbicide should be used once the weed seedlings have emerged in the field. Subsequent weed flushes can be controlled by manual weeding.

Before dissemination of DSR systems across the country, there is a need to develop integrated weed management strategies involving the use of a stale seedbed, high seeding rates, weed-competitive cultivars, narrow row spacing, and economical herbicide combinations for the effective control of weeds.

Table 1. Physical and chemical properties of experimental soil.

Parameter	0-15 cm depth	15-30 cm depth
E.C. (dS m^{-1})	1.2	0.9
Soil pH	7.5	8.0
Organic Matter (%)	0.98	0.55
Nitrogen (%)	0.045	0.028
Available Phosphorous (ppm)	9.5	8.3
Available Potash (ppm)	100	80
Saturation (%)	41	37
Texture	Clay Loam	Loam

Table 2. Weed density (number m^{-2}) before and after treatment application, and weed control efficiency of the treatments during 2010 and 2011.

Treatment	Weeds density before herbicide application		Weeds density after herbicide application		Weed control efficiency (%)	
	2010	2011	2010	2011	2010	2011
Bispyribac sodium	316.5 ^{a}	257.1 ^{bc}	27.2 ^{c}	14.7^{cd}	91.4	94.3
Bispyribac sodium + hand weeding	217.5 ^{bc}	263.4 ^{abc}	12.0 ^{c}	4.4 ^{d}	94.5	98.3
Ethoxysulfuron	221.7 ^{bc}	279.7 ^{a}	59.2 ^{b}	63.6 ^{b}	73.4	77.3
Ethoxysulfuron+ hand weeding	295.2 ^{ab}	263.6 ^{abc}	22.8 ^{c}	18.4 ^{cd}	92.3	93.0
Single hand weeding	191.8 ^{c}	254.3 ^{cd}	28.8 ^{c}	33.2 ^{c}	84.9	86.9
Double hand weeding	254.0 ^{abc}	232.3 ^{d}	7.2 ^{c}	15.0 ^{cd}	97.2	93.5
No weeding	256.8 ^{abc}	277.9 ^{ab}	262.3 ^{a}	305.3 ^{a}	--	-
LSD $_{0.05}$	78.87	22.17	21.74	18.64		

Table 3. Yield and yield attributes of dry seeded rice as affected by different weed management treatments during 2010 and 2011.

Treatment	No. of tillers m^{-2}		Panicle length (cm)		Filled grains $panicle^{-1}$		1000 grain wt. (g)		Grain yield ($t\ ha^{-1}$)	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Bispyribac sodium	303.0^{ab}	257.0^{bc}	25.6 ^{ab}	26.8 ^{ab}	95.0^{bc}	100.5^{bc}	23.24^{a}	22.4 ^{a}	3.1 ^{ab}	3.8 ^{a}
Bispyribac sodium + hand weeding	338.0^{a}	296.7^{a}	27.0^{a}	28.2 ^{a}	116.3^{a}	121.8^{a}	22.47^{a}	23.5 ^{a}	3.2 ^{a}	4.0 ^{a}
Ethoxysulfuron	281.7^{b}	89.7^{e}	21.3^{d}	22.5^{d}	83.3^{c}	88.8^{c}	20.09^{b}	19.09^{b}	2.1 ^{c}	1.7 ^{c}
Ethoxysulfuron + hand weeding	308.3^{ab}	224.3^{cd}	22.4^{cd}	23.6^{cd}	98.3^{bc}	103.8^{bc}	23.23^{a}	21.23^{a}	2.9 ^{ab}	3.3 ^{ab}
Single hand weeding	305.7^{ab}	218.3^{d}	23.0^{c}	24.3^{c}	88.0^{bc}	93.5^{bc}	22.91^{a}	21.91^{a}	2.6 ^{b}	2.7 ^{b}
Double hand weeding	320.7^{ab}	269.3^{ab}	25.2^{b}	26.4^{b}	104.3^{ab}	109.8^{ab}	23.01^{a}	20.01^{a}	3.0 ^{ab}	3.3 ^{ab}
No weeding	99.3^{c}	29.7^{f}	18.2^{e}	19.4^{e}	54.0^{d}	59.5^{d}	19.39^{b}	17.39^{b}	1.1 ^{d}	0.9 ^{c}
LSD $_{0.05}$	47.35	36.90	1.530	1.530	17.79	17.79	1.595	1.595	0.481	0.838

Mean values having the same letters are not significantly different.

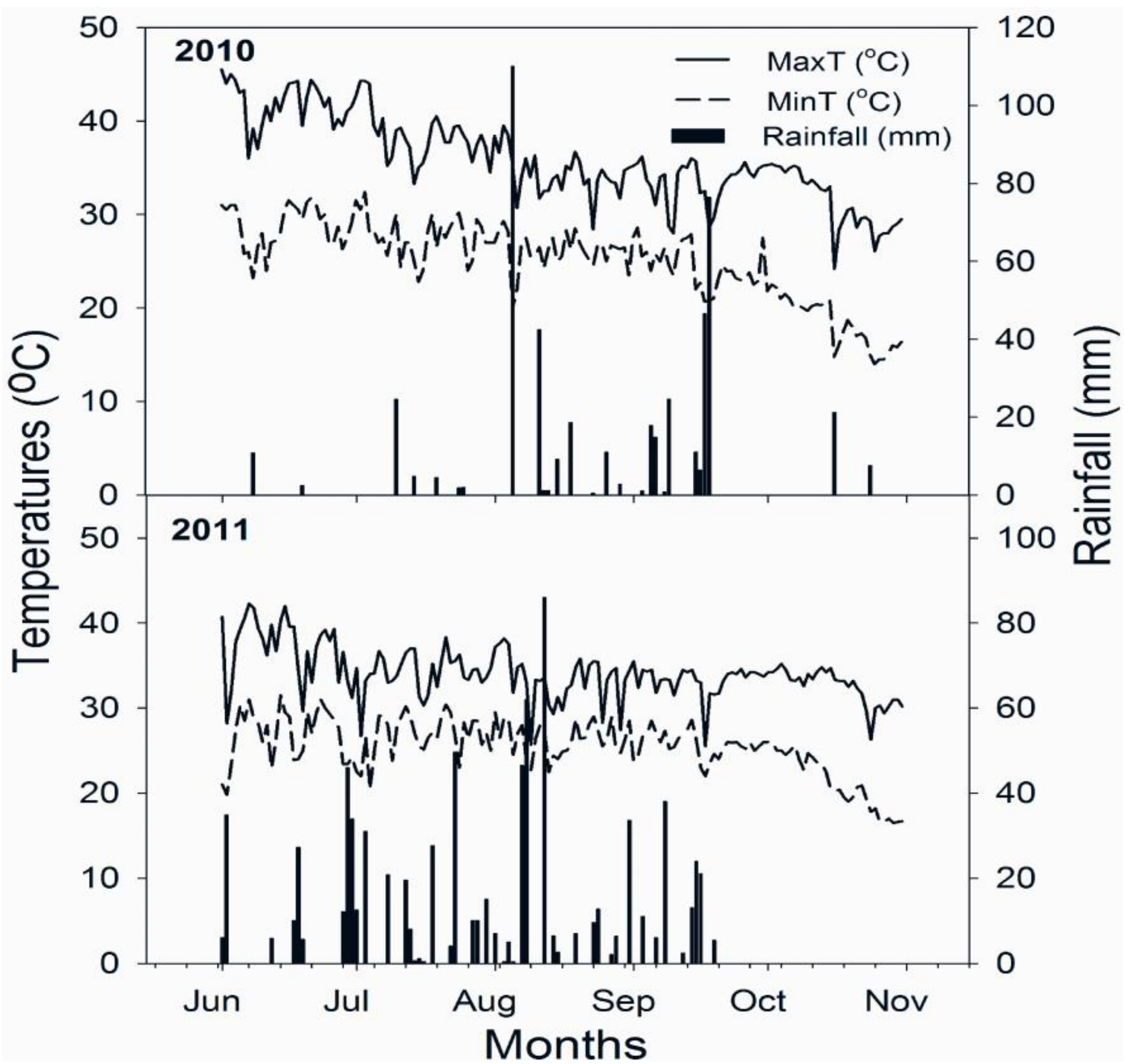

Figure 1. Maximum and minimum temperature, and rainfall during the rice crop season of the year 2010 and 2011.

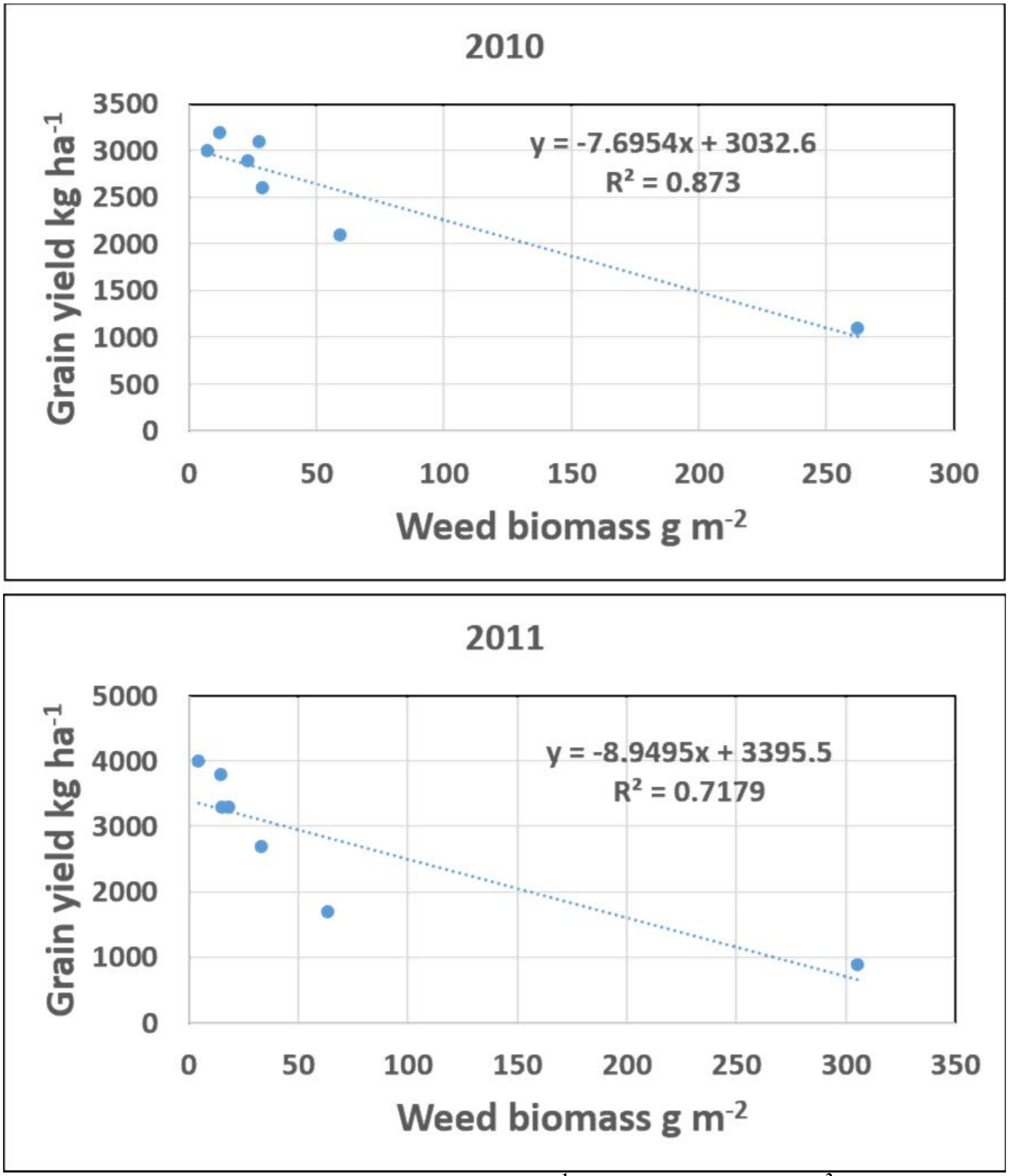

Figure-2. Correlation and regression of rice grain yield (kg ha^{-1}) with weed biomass (g m^{-2}) at 50 days after sowing and after the application of treatments.

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