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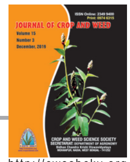

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Bioefficacy of pretilachlor and pyrizosulfuron-ethyl in delaying critical time of competition for *Echinochloa crus-galli* in direct seeded rice

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ABSTRACT

Echinochloa crus-galli is one of the most problematic weeds of rice in Kashmir Valley. In a two-year study to evaluate the application time and efficacy of variable doses of pretilachlor and pyrizosulfuron-ethyl at 3 to 6 days after sowing in direct seeded rice to mitigate and reduce the longevity and emergence of Echinochloa crus-galli using of five herbicide treatments along with two checks (weedy and weed free), a delayed emergence of 45 days was observed in Echinochloa crus-galli when highest dosage of pre-mixed pretilachlor + pyrazosulfuron-ethyl 600 g/ha was applied at sixth day after sowing which was however, statistically at par with pretilachlor + pyrazosulfuron-ethyl 750 g ha^{-1} for 54 days.Individual application of pretilachlor and pyrazosulfuron-ethyl slightly differ in reducing early emergence of Echinochloa crus-galli with an efficacy upto 33 and 29 days, respectively. Critical period was determined as 8-54 days after seeding under different weed control practices during both the years based on conversion of temperature into growing degree days. Visible estimates of rice yield were lowest (54.29 q ha^{-1}) in weedy check and highest in weed free (89.68 q ha^{-1}) followed by pretilachlor and pyrizosulfuron-ethyl 750 g ha^{-1} (88.77 q ha^{-1}).

Keywords: Direct seeded rice, *Echinochloa crus-galli,* critical time, control, yield

Introduction

Globally rice as a staple food is consumed by more than half of the population (Chauhan *et al*., 2015). A possible alternative to conventional rice production is direct seeded rice (DSR), which has the potential to save water, reduce labor, and reduce green house gas (GHG). In the global context, rice production in 2016 was 501.2 million tonnes (milling basis) (FAO, 2017). Adverse interference by weeds is a major factor limiting the productivity of direct seeded rice worldwide (Matzenbacher *et al*., 2013). Due to widespread adaptability and rapid growth, weeds dominate crop habitats and reduce yield potential (Rao and Ladha, 2011). Among various biological stresses, weeds limit the production of direct-seeded rice, especially in aerobic conditions. Under weedy conditions, the yield reduction may ascend up to 70-80% in DSR and 50-60% in puddled transplanted rice (Anchal *et al*., 2017). *Echinochloa crus-galli* (barnyard grass) is one of the most harmful and aggressive weed species in the world. *Echinochloa crus-galli* weeds compete economically with crops and cause serious problems particularly in rice production (Nandhini *et al*., 2019). There are 50 species of this weed that are wide spread in dry or water logged soils in the tropics and temperate regions of the world (Yabuno ,1966; Michael,1983). *Echinochloa crus-galli* and *Echinochloa colona* the most widespread species across the world (Yabuno, 1983); both are worst weeds (Holm *et al.,* 1977), and can cause up to 85-90% yield loss in rice if left untreated (Nandhini *et al.,* 2019). *Echinochloa crus-galli* occurs frequently and in large quantities in all rice production areas of the world and is one of the major weeds affecting production fields (Andres *et al.,* 2007). In addition, herbicides in the rice production system have developed resistance to these weeds (Merotto, 2009; Mariot *et al*., 2010). Critical time of weed control (CTWR) is an integral part of integrated weed management (IWM), which can be considered as the first step in formulating a weed control strategy (Amador and Ramyez, 2002). In the DSR, a critical period of weed competition was reported 14-41 days after sowing (Chauhan and Johnson, 2011). Azmi *et al.* (2007) reported that the critical period for weed control under mixed weed infection in the DSR was 12 to 60 DAS. Early weed control in the growth stages of rice (0 to 40 DAS) helps to improve the productivity of DSR and weeds after this period are not a serious threat to crop production (Maity and Mukherjee, 2008). The use of herbicides in DSR systems is even more important because rice and weed seedlings emerge simultaneously

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and some weed seedlings (*Echinochloa* spp.) are similar to rice seedlings (Chauhan, 2012; Begum *et al.,* 2011). Pretilachlor 50% EC is a pre-emergent, broad-spectrum and systemic herbicide of the chloroacetamide group that controls all types of weeds in rice. It is easily absorbed by hypocotyl, meso-cotyledon, colioptiles and somewhat sprouted weed roots. It works by inhibiting the acetylated synthesis (ALS) required for the synthesis of amino acids. The continuous use of butachlor herbicide for weed control in temperate rice (Kashmir) for the last 30 years has led to the development of butachlor resistant *Echinocola* spp. Applying herbicides as pre-mixed combination in direct seeded rice directly is easy and provides effective weed control even in small quantities. The low-dose-herbicide conforms to the environmental and toxicological profile with excellent control over broad-spectrum activities, grasses, sedges and broad-leaved weeds. The aim of this study was to determine the CTWR of *Echinochloa crus-galli* in Direct seeded rice (DSR) and also to assess the effect of individual and pre-mixed pre-emergent herbicides in delaying its emergence.

MATERIALS AND METHODS

A field experiment was conducted at Agronomy Research Farm, Faculty of Agriculture (34.29^{O}N; 74.47^{O}E), of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India, during *kharif* 2016 and 2017 on clay loam soil, medium (0.72%) in organic carbon and medium in fertility (215 kg N, 20 kg P_2O_5 and 256 kg K_2O ha^{-1}). Annual rainfall in this region is 900-1200 mm year^{-1}, with an average value of 615 mm year^{-1} (Fig.1). The experiment consisted of seven treatments of which five herbicide regimes were tested:1) pretilachlor 50% EC, 2) pyrazosulfuron ethyl 10% WP, 3) pretilachlor 6.0% + pyrazosulfuron-ethyl 0.15% GR (pre-mixed) @ 450 g, 4) pretilachlor 6.0% + pyrazosulfuron-Ethyl 0.15% GR (pre-mixed) @ 600g ha^{-1},5) pretilachlor 6.0% + pyrazosulfuron-ethyl 0.15% GR (Pre-mixed) @ 750 g ha^{-1}, 6) weed free and 7) unweeded check (Table 1). All herbicide regimes with different doses were applied on two different days of sowing in rice (Table 1). Treatments were arranged in a randomized completely block design with three replications for a total of 21 trial plots of size 3 m x 4 m. The effectiveness of all weed control treatments has been tested for the estimated time and critical time of *E.crus-galli* control compared to weed check (no-herbicide application). The timing of crop emergence has been used as a reference point for GDD to reach a base temperature of 10 ^{O}C (Sharma *et al.,* 2008). GDD was calculated as follows:

$$\text{GDD} = \frac{\sum(T\,max + T\,min)}{2} - Tb \quad \text{......................} (1)$$

Here T_{max} and T_{min} are the daily maximum and minimum air temperature (^{O}C), and T_b is lower than the base or entry temperature at which physical activity is inhibited. Weed infection was observed on different days after herbicide application and later. Removal timings were at different growth stages; tillering (V_4), active tillering (V_5), anthesis (V_6) growth stages, grain filling (V_7) and weedy throughout the crop cycle (Table 2). Meteorological data for 2016 and 2017 growing seasons were obtained from meteorological unit Kupwara (Fig. 1). Temperatures were converted from celsius to growing degree days (GDD) to workout time period for *Echinochloa crus-galli* emergence as influenced of herbicides application (Gilmore and Rogers 1958). Yield loss corresponding to weed free check was also calculated as per following equation (2) (Ethann *et al.,* 2019):

$$\text{YL} = 100 \times \left(1 - \frac{\text{P}}{C}\right) \quad \text{..} (2)$$

Here, YL yield loss with respect to weed control, P is the yield of the treatment plot, and C is the yield of the weed-free control plot. Weed indices on density (number per m^{-2}) and dry weights (g m^{-2}) were recorded at 55 DAS. The rice crop (variety Shalimar Rice-4) was sown on 10th may 2016 and 8th May 2017 as pre-germinated seeds in dry soil supplied with immediate light irrigation. Half the dose of nitrogen and full phosphorus and potash was applied as a basal. The remaining half of the nitrogen in two equal splits was applied 25 and 50 days after sowing. The crop is line sown in rows at a distance of 20 cm with sufficient moisture and avoided excessive saturation. Data on panicle (m^{-2}) and panicle weight (g) were recorded and averaged from five randomly selected plants in each experimental unit. Grain yield (qha^{-1}) was recorded by threshing the total individual plots. The predominant weed flora identified during the crop growth are given in Table-2.

Statistical analysis

The data were analyzed through ANOVA technique using the SPS-software with significant difference test at 5% probability to compare the differences among the treatment means. Microsoft Excel program was used to estimate the correlation coefficient between herbicide dosage and delay in weed emergence.

Table 1: Herbicide treatments with dosage applied after sowing (AAS).

Herbicide	Dosage (g/ha)	AAS (days)
Pretilachlor 50 EC	1500	3
Pyrazosulfuron ethyl 10% WP	200	3
Pretilachlor 6.0% + Pyrazosulfuron-ethyl 0.15% GR	450	6
Pretilachlor 6.0% + Pyrazosulfuron-ethyl 0.15% GR	600	6
Pretilachlor 6.0% + Pyrazosulfuron-ethyl 0.15% GR	750	6
Weed free	-	-
Weedy check	-	-

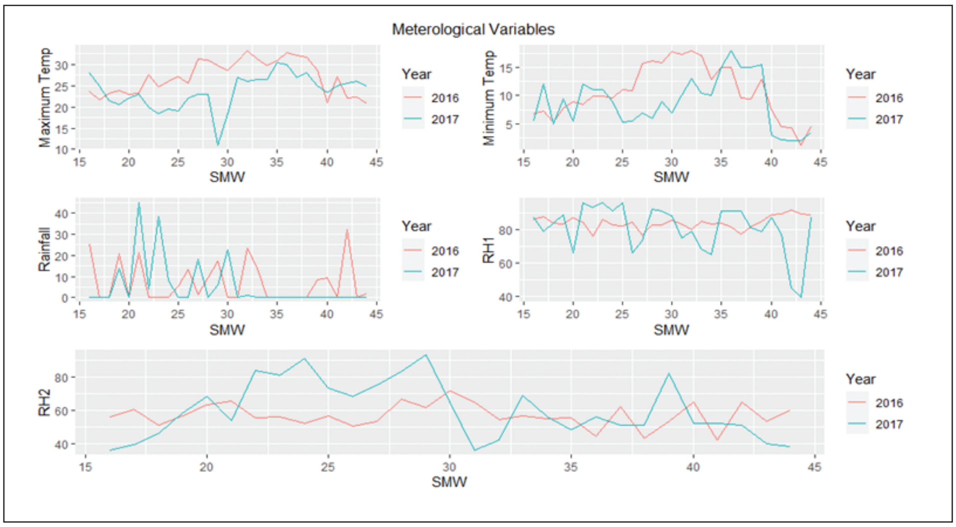

Fig.1: Mean weekly meteorological parameters during growth period of 2016 and 2017

Table 2: Dominant weed flora observed during the experimentation

Weed category	Scientific name	Family	Common name
Grasses	*Echinchloa crusgalli*	Poaceae	Barnyard grass
	Echinochloa colona	Poaceae	Jungle rice
	Cynodon dactylon	Poaceae	Bermuda grass
	Digitaria ciliaris	Poaceae	Crab grass
	Eleusine indica L.	Poaceae	Goose grass
	Chloris barbata	Poaceae	Finger grass
Sedges	*Cyperus iria*	Cyperaceae	Rice flat sedge
	Cyperus difformis	Cyperaceae	Rice sedge
	Cyperus esculentus	Cyperacea	Yellow nut sedge
	Fimbristylis complanata	Cyperacea	Fimbry
Broad leaf weeds	*Ammania baccifera*	Lathyraceae	Monarch red stem
	Xanthium strumarium	Asteraceae	Rough cocklebur
	Alisma plantago-aquatica	Alismataceae	European water-plantain
	Centella asiatica	Mackinlayaceae	Gotu kola
	Cyanotis axillaris	Commelinaceae	Cradle Plant
	Phyla nodiflora	Polygonaceae	Frog fruit

RESULT AND DISCUSSION

Herbicide impact on *Echinochloa crus-galli* emergence and timing of removal

Pre emergent herbicides delayed the critical time of weed removal (CTWR) because of the late emergence of *Echinochloa crus-galli* (Fig. 2). However, the CTWR started much earlier in the plots without pre-emergent herbicide application (weedy and weed free). This was sure as the pre-emergent herbicides helped to control early-emerging weeds, there by delaying the need for post-emergent weed control either by herbicides or manually. These results are in line with Stevan (2019), who reported that pre-emergent application of atrazine, in corn can delay the critical time of weed emergence to the V_5 growth stage. The author also reported that pre-emergent application of Acuron (pre-mixed) further delayed the critical time of weed removal to V_{10} growth stage, which was close to the time of corn canopy closure. The data (Table-3) also revealed that without the pre-emergent herbicide application, the weeds started as early at 156 growing degree days after crop emergence, which corresponded to the V_4 rice growth stage. On the otherside, pre-emergent application of pretilachlor and pyrazosulfuron-ethyl individually or pre-mixed delayed the CTWR upto growing degree days in the range of 501-504, which corresponded to the different growth stages of rice. The early crop-weed competition might be checked due to the variable herbicide regimes with different mode of action achieved by using pretilachlor + pyrazosulfuron-ethyl in rice production. The results are in line with Stevan and Adewale (2020). The data indicates that the critical time for removal of *Echinochloa crus-galli* in rice was delayed by the use of pre-emergent herbicides (Table 3). However, the pre-mixed application of pretilachlor + pyrazosulfuron-ethyl at sixth day after sowing of rice sowing significant delay in weed emergence compared to individual herbicides at third day after sowing. The individual spray of pretilachlor and pyrazosulfuron-ethyl at 3rd DAS increased critical time upto 33 and 29 days, respectively for weed removal which started at the V_3 growth stage in rice, leaving weeds with an opportunity to compete with the crop for next two stages of growth (V_4 & V_5). However, with pre-mixed herbicide (pretilachlor + pyrazosulfuron-ethyl 600 g ha^{-1}) application at 6th DAS, the critical time was delayed upto 45 days after herbicide application corresponding to the V_5 growth stage. Further, the highest dose of pretilachlor + pyrazosulfuron-ethyl 750 g ha^{-1} recorded highest delay of 54 days for critical time of weed control corresponding to V_{10} growth stage which was close to the time of anthesis of the crop (Table 3). This is supported by Anwar, *et al.*, 2012, who revealed that weeds that emerge past the time of anthesis are typically not competitive enough to impact rice yields.This is in line with the results of Adewale and Stevan (2018), who reported that while pre-emergent application of atrazine in corn delayed the critical time of weed control to V_5 growth stage. This confirmed that late spray (6th DAS) of pre-emergent herbicide (pretilachlor + pyrazosulfuron-ethyl 600 g ha^{-1}) delayed the need for early removal of *Echinochloa crus-galli* in rice. Further more, the use of pre-mixed products particularly pretilachlor + pyrazosulfuron-ethyl with multiple active ingredients and/or multiple modes of action has proven to be effective in further delaying the need for post weed control programs in DSR. Our results are in agreement with Adewale and Stevan, 2018 who revealed that the critical time of weed removal with glyphosate was delayed when pre-herbicides were used at 3rd day after sowing in corn.

Efficacy of weed control treatments on density of *Echinochola crus-gali*

The density of *Echinochloa crus-galli* decreased with increase in dose of pretilachlor + pyrazosulfuron ethyl (pre-mix) at 55 DAS during both the years (Table 5). Density of *Echinochloa crus-galli* under pretilachlor + pyrazosulfuron-ethyl @ 600 g/ha was lower (4.29 and 3.15) than its lower dose of 450 g/ha (5.57 and 3.76) during 2016 and 2017, but at par with its highest dose (700 g ha^{-1}), hence 600 g ha^{-1} was realized to be the optimum dose for delaying the emergence of *Echinochloa crus-galli* (Fig 2). Pretilachlor + pyrazosulfuron-ethyl @ 600 g ha^{-1} was superior in efficacy to both pyrazo sulfuron-ethyl 200 g/ha and pretilachlor 600 g ha^{-1} during both the years. However, pretilachlor @ 1500 g ha^{-1} and pyrazosulfuron-ethyl 200 g ha^{-1} recorded significantly lower population (7.4 & 4.09 m^{-2}) of *Echinochola crus-galli* compared to weedy check (96.31 m^{-2}), respectively. The increased density of *Echinochloa crus-galli* initially may be because of aerobic soil conditions, its vigorous growing potential over rice and increasing duration of its interference from sowing time of rice. The results are supported by Dharam *et al*. (2018), who reported that the density of *Echinochloa crus-galli* at 75 DAT decreased with increase in dose of pretilachlor + pyrazosulfuron-ethyl (ready-mix) during both the years. Results of a study in Bangladesh revealed that, for optimal wet-seeded rice productivity, pretilachlor at 250 or 375 g ha^{-1} can be used as an alternative to hand weeding thrice (Rashid *et al*., 2012).

Bio-efficacy of herbicides on dry weight of *Echinochola crus-gali*:

The dry weight of *Echinochola crus-gali* decreased with increase in dose of pretilachlor + pyrazosulfuron-ethyl during both the years (Table 5). All the doses of pretilachlor + pyrazosulfuron-ethyl were at par with each other. During 2016, pretilachlor + pyrazosulfuron-ethyl @ 600 g ha^{-1} was superior to pyrazosulfuron-ethyl @ 200 g/ha, pretilachlor @ 1500 g ha^{-1} and weedy check but at par with Pretilachlor + pyrazosulfuron-ethyl @ 750 g ha^{-1}, and weed free in respect of dry weight of *Echinochola crus-gali*. Pretilachlor @ 1500 g ha^{-1} and pyrazosulfuron-ethyl @ 200 g ha^{-1} recorded significantly lower dry weight (4.07 and 3.25) of *Echinochola crus-gali* compared to weedy check (48.75 gm^{-2}) respectively. During 2017, dry weight of *E. crus-galli* under pretilachlor + pyrazosulfuron-ethyl @ 600 g/ha was at par with all other pre-mixed herbicidal treatments except being superior to pyrazosulfuron-ethyl @ 200 g/ha. Dry weight of this grassy weed (*Echinochola crus-gali*) was similar under all the treatments during 2017. This may be attributed to over come of the higher doses of herbicide residual toxicity and higher efficiency of *Echinochola crus-gali,* which leads to uniform accumulation of dry matter. Results are in line with Dharam *et al*. (2018), who reported that the dry weight of *Echinochola crus-gali* under pretilachlor + pyrazosulfuron-ethyl @ 615 g/ha was at par with all other herbicidal treatments. Similar results were reported by Kumar and Ladha (2011), who reported that follow-up spray of bispyribac after pretilachlor and pyrazosulfuron-ethyl resulted in significantly lower weed dry matter than alone application of pre-emergence herbicides which results in 88% weed control efficiency. Single application of pre-emergence herbicides showed poor weed control efficiency (19.0–24.2%). Chauhan (2013) also reported that pretilachlor plus pyribenzoxim provided greater than 90% control of all weeds. The results are in conformity with findings of Dubey *et al*., 2005; Sanjoy, 2005 and 2009 and Singh *et al.,* 2005.

Residual toxicity of herbicides on rice germination

The degree of residual-toxicity of different herbicide doses to the germinating rice seeds and the symptoms produced in terms of reduction in germination % are presented in Table 4. It is observed from the data that pretilachlor 50 EC @ 1500 g ha^{-1} and Pyrazosulfuron-ethyl @ 200g/ha showed 24.97%, 18.90% and 11.38%, 10.36% decreased germination compared to weed free plot for the year 2016 and 2017, respectively. While as residual toxicity of pretilachlor + pyrazosulfuron-ethyl @ 750 g ha^{-1} showed increasing trend as 13.34 and16.18% for the year 2016 and 2017, respectively. Residual toxicity was observed to note down the germination percentage with different herbicide intensities. It was observed that residual toxicity was more prominent for using single herbicide. Dharam et *al*. (2018) also reported that there was no phyto-toxicity at 3, 7, 15 and 30 days after application of pretilachlor + pyrazosulfuron-ethyl at any of its doses upto 1230 g ha^{-1} on transplanted rice crop during both the years and there was also no residual phytotoxicity of pretilachlor + pyrazosulfuron-ethyl at 615 and 1230 g ha^{-1} at 15, 30, 45, 60 and 75 DAS on the succeeding chickpea and wheat crops.

Effect on yield and yield attributes

Number of effective tillers m^{-2} under pretilachlor + pyrazosulfuron-ethyl @ 600 g ha^{-1} was at par with all other treatments except being superior to pretilachlor @ 1500 g ha^{-1}, pyrazosulfuron-ethyl @ l200 g ha^{-1} and weedy check during both the years (Table 4). Trends in the effects of the treatments on grain yield were similar to the effects on panicle density, and 1000-seed weight. Higher yield realized with second highest dosage of pretilachlor + pyrazosulfuron-ethyl @ 600 g ha^{-1} was statistically at par with highest dosage of pretilachlor + pyrazosulfuron-ethy @ l750 g ha^{-1} (Table 4). Regarding the efficacy of herbicide application, grain yield of direct seeded rice in pretilachlor and pyrizosulfuron individually treated plots were found significantly similar (pretilachlor 82.53 q ha^{-1} and pyrizosulfuron 84.64 q ha^{-1}). This might be due to uniform efficacy of both herbicides in reducing the state of crop-weed competition during critical growth stages of rice. These results are in line with Singh and Pandey (2019), who reported that the early application of herbicide increased grain yield of DSR, however, the average maximum grain yield 87.91 (q ha^{-1}) obtained in herbicide treatment (pretilachlor + pyrazosulfuron-ethyl@750 g ha^{-1}) during both the years was 0.92 q ha^{-1} lower yield than the average yield realized from the weed-free treatment (88.83 q ha^{-1}). Weedy treatment had lowest yield (52.98 q ha^{-1} & 54.29 q ha^{-1}) which was 40.24% and 39.47% lower compared with respective yield under weed free treatment during 2016 and 2017. The reduction of grain yield in weedy check and other treatments was possibly due to severe weed infestation in the crop field (Fig. 5). The weeds growing freely attained a vigour enough to compete with the crop plant for nutrient, moisture and sun-light through out the growing season (Abhinandan *et al*., 2020). However, increased herbicide doses were positively correlated ($R^2 = 0.96$) with delay in *Echinochola crus-gali* emergence as explained by the relationship (Fig. 4). These results were similar to the previous studies in Bangladesh and Philippines and both of which found that grain yield was negatively correlated with weed biomass (Ahmed and Chauhan, 2014; Chauhan and Opeña, 2012). Number of panicles m^{-2}, number of grains per panicle, and thousand-seed weight (g) were increased with the increasing length of weed-free conditions and decreased with the increasing length of weedy conditions. Effective management of *Echinochola crus-gali* consequently resulting into higher yields in transplanted rice due to combined application of herbicides has been realized earlier also by Kumar and Punia (2014), Duary *et al* (2015), Teja (2015). Sangeetha *et al.* (2009) also concluded that pre-emergence application of pretilachlor through starch formulation at 5 kg ha^{-1} was found to be effective in controlling weeds and there by increasing the growth and yield of rice.

CONCLUSION

Understanding the critical time of weed removal (CTWR) is necessary for designing any effective weed management programs in direct seeded rice under temperate production system. The findings of this study suggest that Pretilachlor + Pyrazosulfuron ethyl @ 600 g ha^{-1} applied at the sixth day after sowing in direct seeded rice was found most effective weed control option in delaying the early potential crop-weed interaction by reducing emergence of *Echinochloa crus-galli* weed in comparison to other pre-emergent herbicides doses including hand weeding. Based on the results, yield and yield attributing parameters and weed dynamics were positively influenced by increased doses of pre-emergent herbicides. Further studies are needed to strengthen weed management strategies in DSR based on pre-emergent herbicides as the yield gap was around 17.1 q ha^{-1} between the weed free treatment and pretilachlor + pyrazosulfuron-ethyl @ 600 g/ha^{-1}.

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Table 3: Critical time of weed removal in rice based on 5% yield loss with and without pre-herbicide

Treatments	Dosage (g) ha-1	GDD	EDA	Rice growth stage
Pretilachlor 50 EC	1500	590 (157)	33	Tillering (V4)
Pyrazosulfuron-ethyl	200	480 (102)	29	Tillering (V4)
Pretilachlor + Pyrazosulfuron-ethyl	450	512 (112)	43	Active Tillering (V5)
Pretilachlor + Pyrazosulfuron-ethyl	600	516 (131)	45	Active Tillering (V5)
Pretilachlor + Pyrazosulfuron-ethyl	750	525 (138)	54	Anthesis (V6)
Weed free	-	550 (142)	-	Grain filling (V7)
Weedy check	-	350 (98)	08	Seedling stage

(*The values in parenthesis are original)

Table 4: Germination (%), yield parameters and grain yield of rice as influenced by weed control practices during 2016

Treatment	Germination (%)		Panicles m^{-2}		Panicle weight (g)		Grain yield (q ha^{-1})	
	(2016)	(2017)	(2016)	(2017)	(2016)	(2017)	(2016)	(2017)
Pretilachlor 50 EC 1500 (g)ha^{-1}	63.12	72.15	328.41	329.56	2.51	2.90	82.53	84.64
Pyrazosulfuron-ethyl 200 (g)ha^{-1}	74.56	79.33	327.89	329.04	2.5	2.89	81.47	83.28
Pretilachlor + Pyrazosulfuron-ethyl 450 (g)ha^{-1}	78.42	75.61	322.12	323.27	2.51	2.90	80.35	82.06
Pretilachlor + Pyrazosulfuron-ethyl 600 (g)ha^{-1}	74.81	77.19	342.33	343.48	2.52	2.91	86.27	87.98
Pretilachlor + Pyrazosulfuron-ethyl 750 (g)ha^{-1}	72.91	74.57	345.49	346.64	2.52	2.91	87.06	88.77
Weed free	85.49	89.73	349.14	350.29	2.52	2.91	87.98	89.69
Weedy check	84.13	88.96	261.58	262.73	2.01	2.40	52.58	54.29
SE(m)	**1.11**	**1.56**	**1.42**	**1.54**	**-**	**-**	**0.42**	**0.49**
CD(0.005)	**3.22**	**2.88**	**3.49**	**3.86**	**0.31**	**0.33**	**1.03**	**1.14**

Table 5: Effect of weed control treatments on *E.crus-galli* density and dry weight at 55 DAS in DSR during 2016 and 2017

Treatment	Weed density (No. m^{-2})			Weed dry weight (gm^{-2})		
	E.crus-galli	*E.crus-galli*	Total	*E.crus-galli*	*E.crus-galli*	Total
	2016	2017	Pooled	2016	2017	Pooled
Pretilachlor 50 EC 1500 (g) ha^{-}	2.67 (3.01)*	1.44 (4.11)	2.56 (7.4)	1.91 (0.80)	1.42 (0.53)	3.19 (4.09)
Pyrazosulfuron-e thyl 200 (g) ha^{-1}	2.98 (3.21)	1.63 (2.33)	2.38 (7.2)	2.26 (0.33)	1.43 (0.65)	3.21 (3.25)
Pretilachlor + Pyrazosulfuron-ethyl 450 (g) ha^{-1}	1.22 (1.43)	1.69 (1.26)	2.42 (5.57)	1.66 (2.50)	1.33 (0.56)	3.54 (3.76)
Pretilachlor + Pyrazosulfuron-ethyl 600 (g) ha^{-1}	1.86 (1.16)	1.26 (1.23)	1.87 (4.29)	1.68 (1.22)	1.22 (0.45)	2.26 (3.15)
Pretilachlor + Pyrazosulfuron-ethyl 750 (g) ha^{-1}	1.56 (1.04)	1.89 (1.09)	2.33 (3.21)	2.67 (1.30)	1.48 (1.26)	3.09 (3.03)
Weed free	1.54 (0.78)	1.20 (0.62)	1.73 (0.3)	1.51 (1.06)	1.32 (0.56)	0.11 (1.12)
Weedy check	1.95 (85.44)	1.61 (76.32)	2.51 (96.31)	3.70 (2.40)	2.43 (5.19)	6.88 (48.75)
SE(m)±	**0.12**	**0.14**	**0.13**	**0.052**	**0.073**	**0.0.63**
CD (5%)	**0.28**	**0.53**	**0.42**	**0.18**	**0.22**	**0.19**

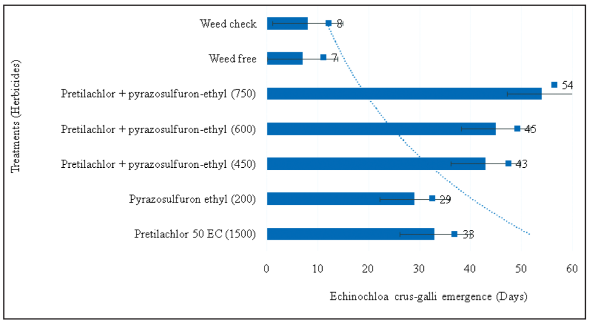

Fig. 2: Influnce of pre-emergent herbicides in delaying the emergence of *Echinochloa crus-galli* after application

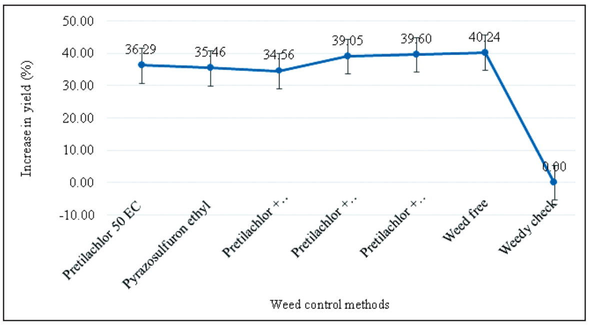

Fig.3: Increase in rice yield (%) as influenced by different weed control methods with reference to weedy check

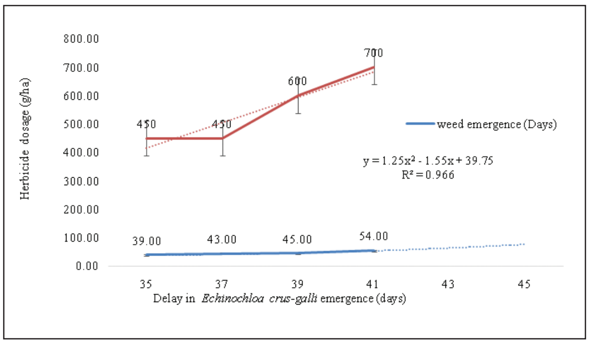

Fig 4: Logistic equation showing strong correlation between incresas in dosage of Pretilachlor + Pyrazosulfuron-ethyl in delaying emergence of *Echinochloa crus-galli*

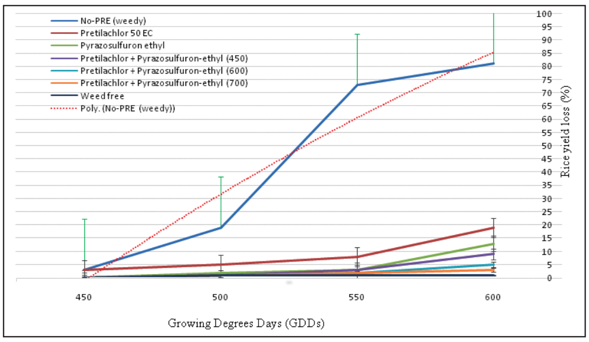

Fig. 5: Rice yield loss as influenced by different weed control methods

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