# RESPONSE OF RED RICE (*Oryza sativa L.*) TO IMIDAZOLINONE HERBICIDES AT DIFFERENT SEEDING DATES

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## INTRODUCTION

Red rice (*Oryza sativa*) is a troublesome weed in most world regions where rice is grown, including in the Southern Brazil. Since 2004, Clearfield® technology has been the main method employed by rice growers to control red rice in Southern Brazil. This technology uses rice genotypes with tolerance/resistance to imidazolinone herbicides, which inhibit acetolactate synthase (ALS), a key enzyme in the biosynthesis of branched-chain amino acids leucine, isoleucine and valine (AVILA et al., 2005). Despite its efficiency on weed control, several red rice biotypes have evolved resistance to these herbicides after few years of the technology use.

The widespread occurrence of imidazolinone-resistant (IMI) red rice led rice growers to include multiple management practices to successfully control this weed. The most effective traditional practice used is to rotate rice with soybean allowing the use of non-selective herbicides and alternative pre-emergent treatment options (BURGOS et al., 2011). On the other hand, in some areas where crop rotation is not possible, early seeding date can be adopted to mitigate yield losses caused by red rice competition, since red rice emergence is reduced at low soil/air temperature (SHIVRAIN et al., 2009). In this context, the imidazolinone herbicides would be applied under lower temperatures in the IMI-rice field seeded earlier than regular or late seeding date.

Limited information is available concerning the effect of seeding date on red rice control with imidazolinones in paddy rice. Most studies conducted have focused on red rice emergence characteristics and yield losses due to interference (SHIVRAIN et al., 2009). As temperature can vary between seeding date or even before and after herbicide application, it is important to determine its effects on imidazolinone efficacy. Understanding of these interactions will provide to rice growers a better management of red rice in the Clearfield® production system. Therefore, this study aimed to evaluate the response of red rice biotypes to imidazolinone herbicides at different seeding dates.

## MATERIAL AND METHODS

The study was carried out under greenhouse conditions from September to December of 2012 at the Centro de Estudos em Herbologia, Faculdade de Agronomia Eliseu Maciel, Universidade Federal de Pelotas, Capão do Leão, Rio Grande do Sul - RS, Brazil. Two red rice biotypes, identified as AV 109 and AVsus, were obtained from Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil. The biotypes were collected in rice fields located in southern Brazil (RS State). The AV 109 biotype was determined as imidazolinone-resistant due to ALS gene mutation $Gly_{654}Glu$ (ROSO et al., 2010). AVsus was confirmed as

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susceptible to imidazolinone in whole-plant bioassay and molecular characterization in previous studies.

The experiment was conducted using a randomized complete block design in a factorial arrangement with four replications. The factor A included two seeding dates, which were September 19th and November 1st (corresponding to early and late seeding date, respectively). The factor B was the red rice biotypes described above. The factor C included five herbicide rates (0.25; 0.5; 1; 1.5 and 2.0 times the recommended rate of imazapyr + imazapic) plus an untreated check. The labeled rate of imazapyr + imazapic was 73.5 + 24.5 g a.i. $ha^{-1}$, respectively.

Ten seeds of each red rice biotype were sowed in a 10-cm diameter by 20-cm high pots containing 400 g of soil and covered with 1 – 2 cm of substrate. Soil moisture was monitored daily and keep in the field capacity. Soil and air temperature was recovery with data loggers (Hobo Pro®) each 15 minutes. Treatment applications were performed using a boon equipped with three flat-fan nozzles (Teejet XR11002) spaced at 50-cm apart. Boom was coupled to a $CO_2$-pressurized backpack sprayer calibrated to deliver 150L $ha^{-1}$ of spray solution at 172kPa. Treatments were sprayed on October 10th and November 17th for the first and second seeding date, respectively. All treatments included nonionic surfactant (Dash®) at 0.5% v/v. Red rice plants were at 3 to 4 leaf stage in the moment of herbicide application.

Red rice control was evaluated at 7, 14, 21 e 28 days after herbicide applications. Red rice control was estimated visually using a scale of 0 to 100% where 0 = no red rice control and 100 = total red rice control. After 28 days plants were harvested and dried in an oven at 60 ºC to determinate the weight of dry matter.

Data were tested of the assumptions of experimental design (independence, homogeneity and normality) and then, subjected to ANOVA. Non-linear exponential models were used to obtain $CT_{50}$ (herbicide rate required to 50% red rice control) and $GR_{50}$ (herbicide rate required to 50% dry weight reduction) from red rice control (equation 1) and shoot dry matter variables (equation 2).

$$Y = a * (1 - \exp^{-b*X}) \qquad \text{eq. (1)}$$

$$Y = Y_0 + a * (\exp^{-b*X}) \qquad \text{eq. (2)}$$

Equation 1 is an asymptotic regression where Y = red rice control, a = maximum red rice control, b = slope of the curve, and X = herbicide rate, while equation 2 is an exponential decay regression where Y = shoot dry weight, $Y_0$= maximum shoot dry weight reduction, a = point of inflection, b = slope of the curve, and X = herbicide rate. Resistance ratio was based on $CT_{50}$ e $GR_{50}$ values of resistant and susceptible biotypes. Ninety-five percente confidence intervals were used to compare these parameters between biotypes.

## RESULTS AND DISCUSSION

Seeding date had little and no effect on sensitivity of the red rice biotypes to imidazolinone herbicides. Differences across seeding date were observed only to IMI-susceptible biotype accordingly to red rice control evaluation (Figure 1). IMI-susceptible biotype required almost 3-fold more herbicide rate on September than November to achieve 50% control (Table 1). Differential sensitivity observed in the susceptible biotype might be associated to environmental factors that after influence absorption, translocation and metabolism of the imidazolinone herbicides in red rice.

Results with other weed species such as pitted morningglory (*Ipomoea lacunosa* L.) showed that variation in temperature had no effect on absorption of imazethapyr, but the acropetal distribution of this herbicide increased when temperature increase from 18 to 35 ºC (KENT et al., 1991). Additionally, temperature has also effect on crop metabolism. Injury of corn seedlings from soil residues of imazaquin was reduced at 18 and 24 ºC soil temperature, because more herbicide was metabolized in shoot tissue than at 12 ºC (POLGE & BARRET, 1997).

**Table 1.** Regression equation, $CT_{50}$, $GR_{50}$ and resistant to susceptible ratio (R/S) values for IMI-resistant and IMI susceptible biotypes accordingly to seeding dates. Capão do Leão, RS, 2012.

| Seeding date | Biotype | Regression equation | $R^2$ | $CT_{50}$ [1/] | R/S [2/] |
|---|---|---|---|---|---|
| september | resistant | $Y=83*(1-exp^{-0.75*X})$ | 0.92 | 1.21 | 2.32* |
| | susceptible | $Y=90*(1-exp^{-1.54*X})$ | 0.95 | 0.52 | |
| november | resistant | $Y=81*(1-exp^{-0.90*X})$ | 0.90 | 1.06 | 5,58* |
| | susceptible | $Y=84*(1-exp^{-4.73*X})$ | 0.93 | 0.19 | |
| **Seeding date** | **Biotype** | **Regression equation** | $R^2$ | $GR_{50}$ | **R/S** |
| september | resistant | $Y=37,08+64,80*(exp^{-2,30*X})$ | 0,87 | 0,69 | 3,13* |
| | susceptible | $Y=35,67+64,28*(exp^{-6,71*X})$ | 0,92 | 0,22 | |
| november | resistant | $Y=38,30+62,73*(exp^{-1,59*X})$ | 0,85 | 1,05 | 8,75* |
| | susceptible | $Y=28,64+71,33*(exp^{-10,20*X})$ | 0,97 | 0,12 | |

[1/] $CT_{50}$ and $GR_{50}$ are the herbicide rate that causes 50% red rice control and shoot dry weight reduction, respectively.
[2/] R/S ratio were calculated based on $CT_{50}$ and $GR_{50}$ values of resistant and susceptible biotypes.
* ratio is significant as the 95% confidence interval of the two $CT_{50}$ or $GR_{50}$ did not overlap.
[ns] ratio is not significant different as the 95% confidence interval of the two $CT_{50}$ or $GR_{50}$ did overlap.

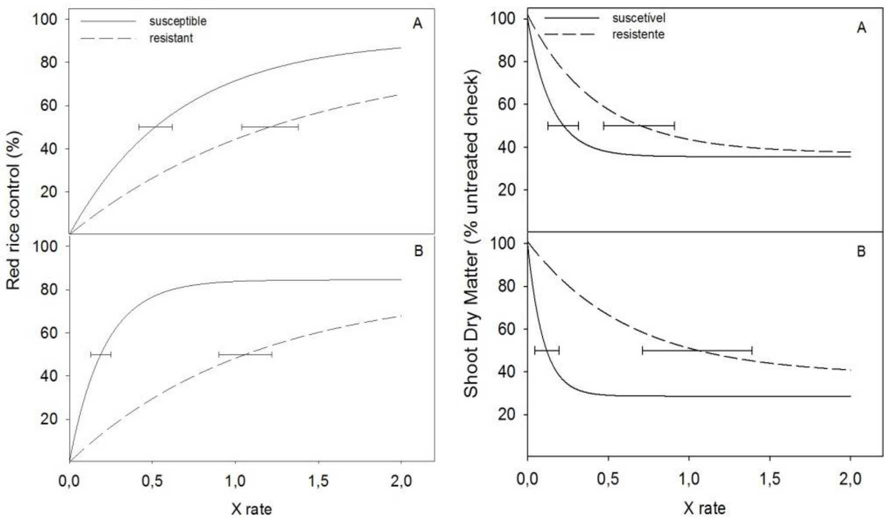


**Figure 1.** Dose response curves for red rice control and shoot dry weight on September (A) and November (B) at 28 DAT. Capão do Leão, RS, 2012. Biotypes are compared at $CT_{50}$ and $GR_{50}$ values using overlapping of 95% confidence intervals.

In this experiment, temperature changed consistently before and after herbicide applications and also across the seeding date (data not shown). Generally, lower temperatures were registered at September than November seeding date. As described earlier in other studies, low temperature reduces herbicide movement into the plant, resulting in less herbicide amount in the target site. To compensate this reduction, higher herbicide rates are required to achieve similar levels of weed control. This hypothesis may explain the differential sensitivity observed in the IMI-susceptible biotype.

IMI-resistant biotype exhibited similar sensibility to imidazolinone herbicides in the two seeding date evaluated. Based on overlapping of 95% confidence intervals, $CT_{50}$ and $GR_{50}$ values were not statistically different between September and November. The similar sensitivity observed for this biotype may be related to resistance mechanism previously identified (ROSO et al., 2010).

## CONCLUSIONS

Seeding date affects sensitivity of IMI-susceptible red rice to imidazolinone herbicides, but has no effect on IMI-resistant biotype to these herbicides.

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