Zooplankton community responses to the mixture of imazethapyr with imazapic and bispyribac-sodium herbicides under rice paddy water conditions

Respostas da comunidade de zooplâncton à mistura dos herbicidas imazetapir com imazapique e bispiribaque-sódico em áreas de arroz irrigado

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ABSTRACT

The aim of this study was to assess the effect of concentrations of imazethapyr, imazapic, and bispyribac-sodium herbicides on zooplankton community (Cladocer, Copepod and Rotifer) in rice paddy fields. The decrease of half-life dissipation (DT50) of the herbicides under study in water was: imazethapyr, imazapic, and bispyribac-sodium with an average of 3.75, 3.73 and 1.91 days, respectively. The mixture of imazethapyr with imazapic caused change in the analyzed zooplankton, with an increase in the densities of Cladocer and adult Copepod groups, while bispyribac-sodium caused a reduction of density in Copepod group, both adults and nauplii, in the initial samples. Among the groups, Rotifer was slightly sensitive to the herbicides.

Key words: imidazolinones, pyrimidinloybenzoic acid, crustacean, cladocera, copepoda, rotifera.

RESUMO

O objetivo deste estudo foi avaliar o efeito das concentrações dos herbicidas imazetapir, imazapique e bispiribaque-sódico na comunidade zooplanctônica (Cladocera, Copepoda e Rotífera) na lavoura de arroz. A diminuição da dissipação de meia-vida (DT50) desses herbicidas em estudo na água foi: imazetapir, imazapique e bispiribaque-sódico, com uma média de 3.75, 3.73 e 1.91 dias, respectivamente. A mistura de imazetapir com imazapic provocou alteração no zooplâncton analisado, com incremento nas densidades dos grupos Cladocera e Copepoda adultos, enquanto que bispiribaque-sódico causou redução de densidade no grupo Copepoda, tanto adulto quanto náuplio, nas amostragens iniciais. Dentre os grupos, Rotífera foi pouco sensível aos herbicidas.

Palavras-chave: imidazolinonas, ácido pirimidiniloxibenzoico, crustáceos, cladocera, copepoda, rotífera.

INTRODUCTION

The worldwide use of herbicides in agriculture for controlling weeds has contributed to the rise of concerns on the contamination of surface and groundwater bodies, and must be considered a potential risk for aquatic life as well as for the quality of drinking water. Even herbicides, such as imazethapyr, imazapic and bispyribac-sodium, and others routinely employed in rice production for the last decades and specifically designed to eliminate weeds, are reported in literature as hazardous at low concentrations, both to aquatic vertebrates and invertebrates (MOORE et al., 1998). Previous researches conducted by PERSCHBACHER et al. (1997), VILLARROEL et al. (2003) (propanil), PERSCHBACHER et al. (2002) (clomazone and quinclorac), and SÁNCHEZ et al. (2006) (profoxydim) showed that herbicides can affect zooplanktonic community. Paddy fields provide habitat for several non-target organisms, such as planktonic species, which play a key role in freshwater ecosystems as they occupy a central position in the food chain, transferring energy from primary producers to organisms at higher trophic levels (CHANG et al., 2005). These organisms constitute an important food source for the numerous predatory insect larvae living in the paddies, all of which help to control rice pest species breeding in this agro-ecosystem (BAMBARADENIYA & AMERASINGHE, 2003).
The commercial formulation of the herbicide Only® is compounded by imazethapyr (2-{[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid}) and imazapic {2-{[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-methyl-3-pyridinecarboxylic acid}}, which are members of the imidazolinone family. These two chemical products present high water solubility, viz. 2200mg L⁻¹ and 36000mg L⁻¹ at 25°C and pH 7, respectively (SENSEMAN, 2007). The commercial formulation of the herbicide Nominee® is composed of bispyribac-sodium (sodium 2,6-bis(4,6-dimethoxypyrimidin-2-yl) benzoylate), which is a member of the pyrimidinylxybenzoic acid family, and is highly water soluble (64000mg L⁻¹) (TARAZONA & SANCHEZ, 2006). These two herbicides inhibit acetolactate synthase (ALS), which is responsible for the biosynthesis of the branched-chain amino acids leucine, isoleucine and valine and are recommended for controlling annual grasses and cyperaceae in irrigated rice in South Brazil (SOSBAI, 2007). Imazethapyr and imazapic form one of the herbicides registered for Clearfield® Production System through a field® Production System through SOI® (2005). Zooplankton community responses to the mixture of imazethapyr with imazapic and bispyribac-sodium herbicides under...
(DT50), i.e. the time taken for the concentration of pesticide to be reduced to 50% of its initial value, was calculated using the equation $DT_{50} = \ln(2)/k$, where $k$ is the absolute value of the slope and first-order rate constant for the herbicide.

Before analysis, the zooplankton data were square root $(x+0.5)$ transformed, where $x$ is the density value. This was done to approximate the data to a normal distribution. The results of the zooplankton groups density were submitted to the two-factor (treatment and days) analysis of variance (ANOVA) for the evaluation of the interaction among them. The means were compared by Fisher’s LSD test ($P < 0.05$) to determine the differences among treatments. The analysis was performed using the SPSS 12.0.

RESULTS AND DISCUSSION

The accuracy, in terms of recovery, for bispyribac-sodium, imazethapyr and imazapic varied from 76.1 to 110.9, 89.3 to 106.7 and 80.9 to 106.6%, respectively. The precision of the method, in terms of relative standard deviation (RSD), presented values <10.1, <7.1 and <5.2%, respectively, for bispyribac-sodium, imazethapyr and imazapic. These results show that the sample preparation and analysis were efficient. Maximum imazethapyr, imazapic and bispyribac-sodium field concentration, measured one day after application was 27 $\mu$g L$^{-1}$ ($SD$ 11.3; $n=3$), 3.1 $\mu$g L$^{-1}$ ($SD$ 0.98; $n=3$), and 22.4 $\mu$g L$^{-1}$ ($SD$ 1.37; $n=3$), that dissipate <0.1 $\mu$g L$^{-1}$ after 28 days, <0.04 $\mu$g L$^{-1}$ after 14 days, and <0.01 $\mu$g L$^{-1}$ after 22 days, respectively. For the persistence of herbicides in water, the initial dissipation times ($DT_{50}$) calculated for imazethapyr and imazapic were <4 days, and for bispyribac-sodium were <2 days, which showed a first-order rate constant ($k$) (Figure 1).

In the present study, rice paddy water herbicide imazethapyr concentrations were detected until 28DAA, and imazapic concentrations were detected until 14DAA. In Brazil, imazethapyr was detected in irrigation water up to 20 days after application with concentration under 5 $\mu$g L$^{-1}$, when applied before permanent flood (SANTOS et al., 2008), and up to 30 days after application, with concentration under 3 $\mu$g L$^{-1}$ (MARCOLIN et al., 2003) when applied after permanent flood. Maximum bispyribac-sodium concentration in 1DAA was 22.4 $\mu$g L$^{-1}$, and it was detected by 21DAA, reinforcing the results obtained by SÁNCHEZ et al. (1999), with initial concentration of bispyribac-sodium in paddy water of 30 $\mu$g L$^{-1}$.

Water quality values, dissolved oxygen concentration, temperature, pH and total hardness showed a significant difference among sampling days. In general, morning dissolved oxygen levels (0.42-6.53mg L$^{-1}$) were higher in the sample taken -3DBA, whereas after application samples remained low until 60DAA. Water temperature ranged from

![Figure 1](image-url)
The pH values (5.4-7.6) decreased in all treatments toward -3 DBA sampling. Thus, it was observed a lower value of morning dissolved oxygen concentration and pH after imazethapyr and imazapic and bispyribac-sodium application in relation to the control treatment. Dissolved oxygen and water pH levels decreased in collected control treatment before herbicide application, possibly due to precipitation occurring between -3DBA and 1DAA of 81mm along four days. Herbicides imazethapyr, imazapic, and bispyribac-sodium, in initial experimental days, provided decreased dissolved oxygen and water pH levels. The same chemical water changes after herbicide application have been demonstrated (GURNEY & ROBINSON, 1989).

The Cladocer group was observed to undergo a change in the organism density because of herbicides when compared to control treatment (Figure 2). Among the sampling days for imazethapyr and imazapic treatment toward 1DAA, there was a significant increase in Cladocers’ density in relation to the -3DBA, remaining until 37DAA. In this same group, a tendency for increasing organism density was observed.

No significant difference between bispyribac-sodium and control treatment was observed to affect Cladocers’ density. The high Cladocers density in imazethapyr and imazapic treatments found in this study, during sampling, corroborates with RELYEA (2009), whose studies suggest that low concentration of atrazine and 2,4-D herbicides have no effect in Cladocers’ survival, or may cause an increase in their population due to high reproduction rate. Cladocer species exposed to the herbicide symetryn were clearly affected, while the majority of Rotifers was less affected and Copepods were apparently not depressed (KASAI & HANAZATO, 1995).

![Figure 2](image-url)
The density of Rotifers increased rapidly when the imazethapyr and imazapic herbicide was applied, but decreased later (3DAA), after which there was an increase where the density remained high until 22DAA. Comparing sampling days, bispyribac-sodium presented an increase of organism density from the 14th until the 37th DAA. As well as Cladocers, Rotifers presented no significant difference comparing the use of this herbicide and control treatment among sampling days. Rotifers presented high density in imazethapyr and imazapic treatment on the 1st DAA. Similar results were observed by PERSchBACHER et al. (1997), when imazquin herbicide, which belongs to the same chemical group (imidazoalnine), was tested. The present study showed Rotifers to be less susceptible to the studied herbicides at tested concentration, as it was found out by HAVENS & HANAZATO (1993); SANDERSON et al. (2004).

Copepod Adults’ density showed an increase after imazethapyr and imazapic application, remaining high until 22nd DAA. However, by comparing organism density obtained in this group to the control treatment in 1st, 14th, 22nd and 60th DAA, it was observed that findings were above the expected for control treatment. Among sampling days, Copepod adults exposed to bispyribac-sodium demonstrated an increase toward 3rd DAA, remaining at a high density until 60th DAA. By comparing Copepod adults’ density to the control treatment, statistics show a significant organism density alteration on the 1st and 22nd DAA.

For imazethapyr and imazapic treatment, no significant difference was found between this compound and control treatment among sampling days. Copepod nauplii, exposed to bispyribac-sodium, showed a decreasing density occurred on the 3rd and 14th DAA, in relation to the control treatment.

According to NEVES et al. (2003), the high densities of the immature forms are generally a result of the continuous reproduction of these organisms in tropical regions. The feeding habits of Copepods vary with the life phase at which they are, since adult Copepods can be carnivores (predators), detritivores and filter-feeders, whereas nauplii are filter-feeders, and frequently herbivores. It is important to point out that within the zooplankton community there is competition for food (bacteria, unicellular algae, among others) and even intra and inter-specific predation. So, toxicant exposure could increase or decrease predation rates in aquatic ecosystems. Even at sub-lethal concentrations, if predators are sensitive, pesticides may affect the survivorship of zooplankton in the presence of predators by controlling prey behavior (HANAZATO, 2001).

Among zooplankton groups, the population lowering rate cannot be attributed directly to applied herbicides, since other biological factors can interact with pesticides, creating consequences for the population of these groups (JAK et al., 1996). According to GAGNETEN (2002), herbicides can provoke zooplankton density reduction, especially among herbivorous crustaceans (Cladocers and Copepods), determine feeding decrease and algae community structure exchanges, presenting toxic effects.

CONCLUSION

During the research period (sixty-three days), the zooplankton community showed distinct responses to the tested herbicides. Most changes occurred in each sample were followed by recovery up to the end of the study. Imazethapyr and imazapic treatment provoked increasing densities of Cladocer and Copepod adult groups. Bispyribac-sodium treatment caused reduction in the density of Copepod adults and nauplii in the initial samples. Rotifers were slightly affected by imazethapyr and imazapic, manifesting fast recovery in relation to the control treatment density.

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