# Management of southern corn rootworm and leafhoppers by treating seeds: field assessments in maize second crop in southern Brazil

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## ABSTRACT

Maize productivity is highly affected by *Diabrotica speciosa* and *Dalbulus maidis* in the second crop seasons in southern Brazil. Thus, this study evaluated the effects of different systemic insecticides tested at recommended doses by seed treatment on the management of these two pest species and assessed the influence of these treatments on maize yield. We conducted a 2-year field experiments (2015/2016 and 2016/2017) at two locations (Chapecó and Guatambú) in Santa Catarina State, Brazil. The experiments were conducted under natural infestation of both pest species, with eight treatments [(imidacloprid, thiamethoxam, imidacloprid+thiodicarb, fipronil, imidacloprid+bifenthrin, chlorantraniliprole, chlorantraniliprole+clothidian (standard used in industrial seed treatment), and a negative control (without insecticides)]. The results showed that seed treatment do not reduce population density of *D. maidis* after 21 days of plant emergence and injuries in the maize root system caused by *D. speciosa* larvae. In addition, insecticides via seed treatment do not affect productivity and crop yield components. Regardless of the location and year, root damage was positively correlated with diameter of the first internode and inversely correlated with grain yield. In this framework, this research suggests that maize seed treatments not always provide economic benefits to farmers, such as pest reductions or yield improvements.

**Keywords:** *Zea mays*, neonicotinoids, pyrazoles, *Diabrotica speciosa*, *Dalbulus maidis*

## INTRODUCTION

The southern corn rootworm, *Diabrotica speciosa* (Germar) (Coleoptera: Chrysomelidae) and corn leafhopper, *Dalbulus maidis* (DeLong & Wolcott) (Hemiptera: Cicadellidae), are serious emerging pest problems of maize crops in Brazil. *D. speciosa* is a polyphagous herbivore that lives in the soil during the larval stage and is usually found in maize roots. *D. speciosa* feeds on corn roots and compromises the capacity of plants to absorb water and nutrients, making it less productive and more susceptible to root diseases and tipping (Capinera, 2008). On the other hand, *D. maidis* is a specialist pest species on *Zea* and relatives (Poaceae) and a vector of three maize pathogens: corn stunt spiroplasma, maize bushy stunt phytoplasma (both bacterial of the Class Mollicutes) and Maize rayado fino virus - MRFV (Oliveira et al., 2015). According to Waquil et al. (1999), yield losses caused by these diseases range from 9 to 90% depending on cultivar susceptibility and on pathogen involved.

Maize second crop in southern Brazil usually starts after early soybean or common bean crops and is characterized by intense pressures of *D. speciosa* and *D. maidis* populations, which reduce yield and compromise the economic viability of farms. In the maize second crop, the

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management of *D. speciosa* and *D. maidis* populations is mostly carried out by synthetic insecticides via seed treatment and sowing furrow as well as in post-emergence of the crop (control of adults). In seed treatment, insecticides should exhibit a residual effect between 6 and 10 weeks for an effective protection in the initial crop phase, during the first occurrences of mollicutes and MRFV transmission and more pronounced damage on maize roots by *D. speciosa* larvae (Ávila et al., 2013). However, constant changes of production systems, climatic conditions, and pest species behavior as well as the occurrence of insect-resistant populations have led to inconsistent results of this chemical control in cornfields.

The effect of any management strategy on pest population levels must be studied and determinations need to be made regarding the strategy efficiency for control objectives. Therefore, given the increasing impact to maize inflicted by *D. speciosa* and *D. maidis* in the second crop in southern Brazil, this study evaluated the effect of different registered systemic insecticides tested by seed treatment on the management of these two pest species and assessed the influence of treatments on maize productivity.

## MATERIAL AND METHODS

The experiments were conducted in the maize second crop in Chapecó (27º05'19"S, 52º38'13"W; elevation: 658 m) and in Guatambu (27º07'55"S; 52º45'38" W; elevation: 570 m), both in Santa Catarina State, Brazil, during the 2015/2016 and 2016/2017 crop years. In both sites and crop years, common bean (*Phaseolus vulgaris* L.) was the predecessor crop. Thirty days before sowing, spontaneous plants were desiccated using the herbicide glyphosate (Roundup Original®) and 2,4-dichlorophenoxy acetic acid (2,4-D Nortox®), at 5 and 2 L ha$^{-1}$, respectively. Sowing was carried out in the second half of January using the hybrid P3340 VYH Liberty Link (Pioneer ®), spacing 0.8 m between rows with average sowing density of 4.8 seeds per meter.

The basic fertilization consisted of 400 kg ha$^{-1}$ of NPK 09-33-12, according to analysis of soil from both sites. In V3 and V8 stages, two applications of glufosinate-ammonium salt herbicide (Finale®) + 0.25% of soybean oil methyl ester (Aureo®) adjuvant were performed at the dosage of 1.5 L ha$^{-1}$, in a mixture volume of 150 L ha$^{-1}$. The application of N under cover was done in V5-V6 stages, using 250 kg ha$^{-1}$ of urea (45% N). For disease control, two applications (V10-V11 and R2-R3) of the fungicide picoxystrobin+ciproconazol (Aproach Prima®, 400 mL ha$^{-1}$) added with mineral oil 0.5% (Assist®) were performed using a Stihl® SR 430 atomizer and a mixture volume of 300 L ha$^{-1}$. The other cultural treatments followed the technical recommendations for maize production in Brazil (Rosa et al., 2017), except for application of insecticides which was not carried out during the entire crop cycle.

The experiments were conducted under a completely randomized design with 8 treatments at recommended doses {[imidacloprid (Gaucho® FS, 800 mL 100 kg$^{-1}$ seeds), thiamethoxam (Cruiser® 350 FS, 120 mL 60 thousand$^{-1}$ seeds), imidacloprid+thiodicarb (CropStar®, 1,500 mL 100 kg$^{-1}$ seeds), fipronil (Shelter®, 100 mL hectare$^{-1}$), imidacloprid+bifenthrin (Rocks®, 1,500 mL 100 kg$^{-1}$ seeds), chlorantraniliprole (Dermacor®, 72 mL 60 thousand$^{-1}$ seeds), chlorantraniliprole+clothidian (standard used in industrial seed treatment, Dermacor® + Poncho®, 48 mL 60 thousand$^{-1}$ seeds + 350 mL 100 kg$^{-1}$ seeds), and a negative control (without insecticides)]} and 5 replicates, totaling 40 experimental units. Each experimental unit was composed of 6 rows of 5 m each, making a useful area of 24 m$^2$. In all treatments, the fungicides composed by fludioxonil + metalaxyl-M (Maxim XL®) and carbendazim + thiram (Derosal Plus®) were added at doses of 1.5 and 3 mL kg$^{-1}$ of seeds, respectively.

Twenty-one days after emergence (DAE), visual counting of adults of *D. speciosa* and *D. maidis* were counted visually on pre-stablished plants (5th, 10th, 15th and 20th plant of lines 3 and 4 of each plot). Plant height (distance between soil and the last expanded leaf) and the number of emerged plants in each plot were also registered. In R1 stage (flowering), pre-stablished plants (5th, 10th and 15th plants of lines 2 and 5) were collected to evaluate the damage caused by corn rootworms, using the scale proposed by Oleson et al., (2005). In addition, the diameter of the first internode of each plant was measured with a digital caliper. Due to the stem elliptical shape, two measurements were made on the stem opposite sides and then the mean of the two measurements was calculated. At physiological maturation, the 2 central lines of each plot (lines 3 and 4) were collected manually to count the average number of cobs per plant and the final population of plants, and measure yield (with 13% of moisture content) and weight of one thousand seeds (WTS).

For the data analysis, firstly, we performed a pre-adjustment of model with normal distribution to the data and, afterwards, we tested the normality of residues in the Shapiro-Wilk test and the homogeneity of variances in the Bartlett test. When the data did not show normality and/or homoscedasticity, we proceeded to a transformation based on the method of maximum power of Box-Cox. When assumptions were satisfied, the data were submitted to analysis of variance by the F test ($p < 0.05$). When there was a significant difference between the treatments, the means were compared by the Tukey test ($p < 0.05$). The correlation between the variables analyzed was determined using the Pearson correlation ($p = 0.05$). All the analyses were carried out using the statistical software "R", version 3.4.3.

## RESULTS AND DISCUSSION

Regardless of the cultivation site and crop year, the insecticides tested through seed treatment did not show any influence on the crop initial population [Chapecó 2015/2016 (F: 0.657, $p$: 0.706); Chapecó 2016/2017 (F: 0.878, $p$: 0.534); Guatambu 2015/2016 (F: 1.676, $p$: 0.151) and Guatambu 2016/2017 (F: 1.752, $p$: 0.132)] and average number of *D. speciosa* [Chapecó 2015/2016 (F: 1.197, $p$: 0.332); Chapecó 2016/2017 (F: 1.693, $p$: 0.146); Guatambu 2015/2016 (F: 0.41, $p$: 0.889) and Guatambu 2016/2017 (F: 0.609, $p$: 0.744)] and *D. maidis* [Chapecó 2015/2016 (F: 0.887, $p$: 0.528); Chapecó 2016/2017 (F: 1.587, $p$: 0.175); Guatambu 2015/2016 (F: 0.61, $p$: 0.743) and Guatambu 2016/2017 (F: 0.926, $p$: 0.50)] per plant as well as on the height of plants 21 days after maize emergence [Chapecó 2015/2016 (F: 0.341, $p$: 0.929); Chapecó 2016/2017 (F: 2.15, $p$: 0.0663); Guatambu 2015/2016 (F: 0.776, $p$: 0.612) and Guatambu 2016/2017 (F: 0.704, $p$: 0.668)]. Despite the high natural incidence of corn leafhoppers, which varies according to the year and site, no incidence of the diseases transmitted by *D. maidis* was observed, possibly due to the low frequency of pathogens in the insect population, temporal and spatial isolation of areas in relation to other cornfields and resistance of the hybrid used.

The maize seed treatment did not show any influence on root damage (assessed by damage note scale) caused by corn rootworms [Chapecó 2015/2016 (F: 0.67, $p$: 0.696); Chapecó 2016/2017 (F: 1.369, $p$: 0.252); Guatambu 2015/2016 (F: 0.334, $p$: 0.927) and Guatambu 2016/2017 (F: 2.334, $p$: 0.0.052)] and on the diameter of the first internode when assessed in full bloom of maize plants [Chapecó 2015/2016 (F: 1.231, $p$: 0.315); Chapecó 2016/2017 (F: 3.089, $p$: 0.0133); Guatambu 2015/2016 (F: 0.995, $p$: 0.453) and Guatambu 2016/2017 (F: 0.724, $p$: 0.653)], except for Chapecó (2015/2016), where most treatments (thiametoxan, imidacloprid+thiodicarb, fipronil, imidacloprid+bifenthrin, chlorantraniliprole, chlorantraniliprole+clothianidin, all at registered doses) caused a small reduction in the diameter of the first internode. Regardless of the site, crop year and treatment, root damage was positively correlated with diameter of the first internode ($r = 0.5974$; df = 158; $p<0.0001$) and inversely correlated with grain yield ($r = -0.4490$; df = 158; $p<0.0001$).

At physiological maturation, the tested insecticides via seed treatment did not affect the final stand (plants/hectare) [Chapecó 2015/2016 (F: 0.401, $p$: 0.895); Chapecó 2016/2017 (F: 0.36, $p$: 0.918); Guatambu 2015/2016 (F: 1.463, $p$: 0.2116) and Guatambu 2016/2017 (F: 1.035, $p$:

0.426)] and the assessed yield components: weight of one thousand seeds [Chapecó 2015/2016 (F: 1.796, *p*: 0.122); Chapecó 2016/2017 (F: 0.32, *p*: 0.939); Guatambu 2015/2016 (F: 0.818, *p*: 0.579) and Guatambu 2016/2017 (F: 0.721, *p*: 0.655)] and grain yield [Chapecó 2015/2016 (F: 0.398, *p*: 0.896); Chapecó 2016/2017 (F: 0.613, *p*: 0.741); Guatambu 2015/2016 (F: 1.606, *p*: 0.171) and Guatambu 2016/2017 (F: 1.166, *p*: 0.35)], regardless of the cultivation site and crop year. In general, the 2016/2017 crop year had higher yields than the 2015/2016 harvest, due to better climatic conditions (data not shown).

Our results showed that maize seed treatments did not provide economic benefits to farmers through pest reductions or yield improvements in areas where southern corn rootworm and leafhoppers are the main phytosanitary problems (mainly in *Bt* maize crops). Therefore, integrated strategies should be designed for *D. speciosa* management including maize crop rotation with other non-host crops, soil application of insecticides at planting, use of *Bt* rootworm transgenics, and foliar insecticide treatments. Management strategies for *D. maidis* should include the synchronism of the planting date, use of cultivars/hybrids resistant to transmittable diseases (corn stunt, maize bushy stunt and maize rayado fino virus), chemical control of insect vector in crop post-emergence and elimination of maize volunteer plants during offseason and alternative hosts (Oliveira et al., 2013). Notwithstanding, more accurate information is necessary for a safer recommendation of these strategies within an integrated pest management program and crop management.

## CONCLUSION

In maize second crop in southern Brazil, the use of insecticides in seed treatment does not reduce the population density of *D. maidis* after 21 days of plant emergence and the injury caused by *D. speciosa* larvae to the maize root system. In addition, the use of insecticides via seed treatment does not affect yield and crop yield components.

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