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Scientific paper

Evaluation of maize hybrids conventional and transgenic (*Bt*), with different insecticide application, on second-crop

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Abstract

Brazil is the third largest producer of corn (*Zea mays* L.) in the world, and this place could rise, due to the intensification and investments in technology. This work aims to evaluate the effect of the number of insecticide applications in *Bt* and conventional maize hybrids in the variables: plant height (cm), height of ear insertion (cm) and yield (kg ha^{-1}), in no-tillage system, and it was used the same inputs and cultivation for all treatments. The experiment was conducted in plots divided in with randomized treatments, with 3 treatments and 4 replications. Each plot had one row of 6 m of length and 0.6 m of spacing within rows and plants spaced 0.2 m between plants in the "off season" in 2010, the city of Cascavel/PR, Brazil. By observing the behavior of the variables, it can be inferred that three applications had the highest values of plant height and productivity; for insertion, no differences were found with the treatments with one and three applications, however, outperformed treatment one two applications. The highest yield occurred in hybrid IMPACTO TL with 6205.75 kg ha^{-1}.

Key words: *Zea mays*, adaptability, transgenic and conventional.

Introduction

Maize is cultivated in the most different climates and environments of the planet, from the latitude 40° S to 58°N and altitude up to 3000 m, due to its high degree of domestication. It is accepted three hypotheses for the origin of maize, which relate its origin with "teosinte" (*Euchlaena mexicana*) and "tripsacum". The first hypothesis is that maize, teosinte and tripsacum had a common ancestral; the second hypothesis is that maize came from teosinte, and the third hypothesis is that teosonite cam from maize (BUCKLER and STEVENS, 2005). Over the years, the high level of domestication and the genetic breeding made the plant completely dependent on the human action.

Gradually, it has been observed evolution in gain of productivity in the cultivation of the maize off-season, showing that the producers have made more investments and used mote technologies recommended for the crop. Among the factors of production which have received attention by farmers are the choice of cultivars, the right positioning of cultivars in the different regions of cultivation, the planting in the most recommended period, the balanced fertilization, the use of fungicides, the environment of production, the price of commercialization of the grains, which are factors that may produce results and consequently dilute the cost which are inherent of the productive system (SHIOGA et al., 2007).

Great changes in the increase of the production of the maize "off-season" in Brazil since the beginning of the decade of 1990 have caused changes in the seasonal standard of the price of cereal received by the producers, thus, with the higher offer of maize in the period of "off-season", there was reduction of price variation, i.e., between the maximum and minimum prices of the year, there was a small range (TSUNECHIRO et al., 1999).

The agronomical implications of the higher explosion of the crop to the environmental stress with

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increase in the planted area in different regions and with different levels of technology applied, allied to the increase of plagues and diseases, have been a great challenge for the public and private institutions of research in the generation of appropriate technologies for the solution of the problems which come from the space and time displacement that the maize crop has been suffering (TSUNECHIRO and GODOY, 2001). The current research is to maximize the productivity of the crops and the nutritive value of each maize cultivar or hybrid, aiming at continuing to obtain the sustainability in the rural mean (GOMES et al., 2002).

Currently, in many countries, large-scale and small producers have the benefits of the maize developed by Biotechnology, also called genetically modified (GM) and present higher competitiveness, mainly considering the reduction of the number of applications and of agrochemicals (QAIM and MATUSCHKE, 2005). According to JAMES (2003a and 2003b), experiments in fields made in Brazil obtained an average gain in productivity for *Bt* maize (*Bacillus thuringiensis*) of approximately 16 to 24% when compared to the conventional maize. In Argentina, James (2003a) analyzed that the productivity of maize *Bt* was in average 10% superior to the conventional plants of maize. Studies made in the Corn Belt in the United States evaluating the impact of *Bt* maize verified a gain in productivity of the transgenic plants in the order of 5 to 12% (MARRA et al., 2002).

According to BORCHGRAVE (2002), with the adoption of genetically modified maize, the farmers would count on an increase of 5% in the productivity and would save 50% in insecticides. The results showed that the adoption of the *Bt* maize, containing the protein Cry1A_ (used in maize, containing the technology TL and YG) improves the access of the producers to the technology for the control of the main maize plagues, the elimination of the plagues improve the maize productivity, and eliminates the necessity of use of insecticides to control the main plagues which affect the crop, reducing the environmental impacts.

Armyworm (*Spodoptera frugiperda* Smith) is the main plague of the maize crop in Brazil. CARVALHO (1970) registered a loss of grain yield from 15 to 34%, in which the damage caused by the plague harmed the plant development, and reduced the mass of the ears produced, when the maize plants presented ears destroyed by the attack. CRUZ and TURPIN (1982) evidenced the reduction in the maize grain yield of approximately 19%, when artificial infestations were performed in plants in the stage from 8 to 10 leaves, near to 45 days after seeding.

Some cases of application of insecticides presented inefficiency, as it was observed in Cruz Alta, Fortaleza dos Valos and Pejuçara – RS, especially in the periods of planting from November to January, which are coincident with periods of draught. These problems demand researches about the possible causes of failure, aiming to equate them, in order to improve the control of the plague. Among the factors which may influence negatively the efficiency of insecticides in the control of the armyworm in maize are the late combat and inappropriate methods of application or as technology of application of insecticides with more scarce equipments (ALMEIDA et al., 1964 and 1966; CRUZ and SANTOS, 1984).

The objective of this work was to identify the influence of the insecticide in the productivity of maize grains, as well as to find hybrids which are more adapted and with higher productive potential for the cultivation "off-season" in the west region of Paraná.

Material and methods

The experiment was performed in the research company Syngenta Seeds Ltda. In Cascavel – PR, with latitude of 24º 56' 26" S and longitude 53º 30' 36" W and an altitude of 760 meters, in a Latossolo Vermelho Distrófico[1]. According to the climate classification of Köppen, the climate of the region is characterized as Cfa – Subtropical climate (CAVIGLIONE et al., 2000). The annual average temperature is 19.6 °C, the annual rainfall 197 mm and the insolation of 2462 hours per year (IAPAR, 2011). The maize seeding was performed in January 30, 2010 (crop "safrinha").

In the experiment it was evaluated the behavior of 16 maize hybrids: Celeron, Celeron TL, Formula, Formula TL, AG9010, AG9010 YG, Sprint, Sprint TL, Impacto, ImpactoTL, DKB390, DKB390 YG, Penta, Penta TL, Status e Status TL (Table 1), 8 conventional hybrids and 8 transgenic hybrids (Bt), the hybrids can also be divided in cycles with 16 hybrids, in which: 8 are early, and 8 are super-early (Table 1), all indicated and commercialized as "off-season" for the west region of Paraná and they were tested in a different number of times in which it was applied insecticide.

1 Brazilian soil classification

Table 1. Hybrids of maize used in the experiment

Hybrids	Ogm	Cycle	Company	Hybrids	Ogm	Cycle	Company
Celeron	No	Super-Early	Syngenta	Impacto	No	Early	Syngenta
Celeron TL	Yes	Super-Early	Syngenta	Impacto TL	Yes	Early	Syngenta
Formula	No	Super-Early	Syngenta	Dkb390	No	Early	Monsanto
Formula TL	Yes	Super-Early	Syngenta	Dkb390 YG	Yes	Early	Monsanto
Ag9010	No	Super-Early	Monsanto	Penta	No	Early	Syngenta
Ag9010 YG	Yes	Super-Early	Monsanto	Penta TL	Yes	Early	Syngenta
Sprint	No	Super-Early	Syngenta	Status	No	Early	Syngenta
Sprint TL	Yes	Super-Early	Syngenta	Status TL	Yes	Early	Syngenta

Ogm = organism genetically modified

The experiment design used was blocks with randomized treatments and split-plot, in which concerning plot it was the number of application in three different levels; with one application, two applications and three applications, and sub-plots the 16 hybrids, making a total of 48 treatments. Each treatment was constituted by 4 rows of 6 meters of length with spacing of 0.6 meters between lines and 0.2 meters between plants. Besides the insecticide, the other cultural treatments were bases in the standard used by the agriculturers in the region.

The experiment area was divided in 3 plots, in which it was performed application in three steps – the first application was in all plots, the second step performed from the second plot and the third step performed only in the third plot (Table 2). The applications were performed both in *Bt* and conventional hybrids. Besides the named applications of insecticide, it was performed an application of fungicide Priori Xtra in all the experiment in the phase of pre-flowering.

The analyzed variables were: plant height in meters (PH), first pod insertion in meters (PI) and grain yield (GY) in kg ha^{-1}. It was verified the basic assumptions as homogeneity of the variances and the results of the analyzed variables were submitted to the analysis of variance and test of grouping of averages by Scott and Knott (1974), using the statistic program SISVAR.

Results and discussion

From the analysis of variance (Table 3), it was analyzed the results for the variables grain yield (GY), plant height (PH) and height of first pod insertion (PI).

Grain yield presented significance by the F test at 1% of significance; the number of applications, kinds of hybrids and the interactions between these sources of variation, indicating thus that the hybrids act in a different way according to the number of application of insecticide. For this variable, similar results were obtained by WAQUIL et al. (2002).

For plant height and height of pod insertion, the presented significance for number of applications, hybrid composition, and for the interaction application x hybrid, it presented significance only for the height of first pod insertion. From these results, it is observed the existence of variability and distinction between hybrids and the variables analyzed in the experiment.

When it is analyzed Table 3, it can be verified that the coefficients of variation (CV%) present values from low to medium (SCAPIM et al., 1995). For the characters of grain yield (GY), plant height (PH) and ear insertion (EI), the mean values of the experiment can be considered good for the region and season of seeding ("off-season"), considering as base the experiments of state evaluation of maize cultivars off-season conducted by IAPAR (SHIOGA et al., 2010). It can be emphasized that due to the planting

Table 2. Number of applications of insecticide in different doses and periods

Aplication	Product [1]	Dosage	Period	Area
1ª Aplication	ENGEO + KARATE	200 and 100 ml ha^{-1}	7 D.A.S.	100%
2ª Aplication	KARATE + MATCH	100 and 300 ml ha^{-1}	15 D.A.S.	66.66%
3ª Aplication	KARATE + MATCH	100 and 300 ml ha^{-1}	25 D.A.S.	33.33%

D.A.S. = days after seeding *[1] from the authors preference the products are presented with the commercial name in Brazil*

Table 3. Analysis of variance in experiment with split-plot, for plant height (PH), height of pod insertion (PI), height of ear insertion (EI) and yield

		Yield		Plant height		Height of ear insertion	
SV	DL	MS	F	MS	F	MS	F
Block	2	87,591.57		0.005		0.010	
Application (A)	2	26,394,221.13	**	0.057	*	0.092	*
Error (a)	4	509,563.85		0.008		0.008	
Hybrid (H)	15	3,964,596.89	**	0.151	**	0.168	**
H x A	30	2,005,348.15	**	0.003	ns	0.010	*
Error (b)	90	600,820.02		0.005		0.010	
Total	143						
CV%		16.20		3.19		9.23	
Mean		4784.06 kg ha-1		2.16 m		1.07 m	

***, * = significance at 1% and 5% of probability by F test; ns = non significant; SV = source of variation; GL = degree of liberty; MS = mean square; CV = coefficient of variation.*

in period considered as ideal, there was no negative effects of frost in this experiment.

In Table 4, it can be observed the test of mean comparison for the variable yield of the 16 hybrids of maize (conventional and transgenic) evaluated, in relation to the number of applications of insecticide.

For grain yield (Table 4) with one application the hybrids IMPACTO and IMPACTO TL are noteworthy, with two applications, the hybrids CELERON TL, IMPACTO TL and STATUS TL are noteworthy, and with three application, the hybrid CELERON was the most noteworthy. It can also be verified that, in the overall average of number of applications, there was a significant difference, observing that three applications presented values superior to 25.01% and 19.75%, when it was compared to one and two applications, respectively.

In Table 5, it can be seen the results of the test of mean comparison for the variable plant height for the evaluated hybrids in relation to the number of application of insecticide.

Hybrids STATUS, STATUS TL and CELERON TL presented high plant height (Table 5) in the three levels of application of insecticide, and were classified

Table 4. Test of grouping means for the variable grain yield with different number of applications of insecticide

	Yield (kg ha^{-1})						
Hybrids	1 Aplication[1]		2 Aplications [1]		3 Aplications [1]		Mean
Celeron	3760.8	b	3951.9	b	8277.7	a	5330.1
Celeron TL	4216.3	b	5942.5	a	4809.2	c	4989.3
Formula	4374.5	b	4574.8	b	6407.3	b	5118.9
Formula TL	4717.7	b	4439.4	b	4728.4	c	4628.5
Ag9010	3445.2	b	4022.8	b	4924.2	c	4130.7
Ag9010 YG	4332.7	b	4145.9	b	5402.9	c	4627.2
Sprint	4399.4	b	4543.0	b	6118.1	b	5020.2
Sprint TL	3773.1	b	2931.1	b	4314.0	c	3672.7
Impacto	5977.5	a	4684.6	b	6088.9	b	5583.7
Impacto TL	6112.2	a	6157.6	a	6347.5	b	6205.8
Dkb390	2001.6	c	4581.3	b	6022.2	b	4201.7
Dkb390 YG	3504.1	b	3974.4	b	3849.1	c	3775.9
Penta	3537.1	b	4248.6	b	5742.1	b	4509.2
Penta TL	4501.3	b	3954.6	b	5086.1	c	4514.0
Status	4184.9	b	4867.0	b	6345.3	b	5132.4
Status TL	4626.6	b	5181.2	a	5506.5	c	5104.8
Mean[2]	4216.6	C	4512.5	B	5623.1	A	

[1,2] Means followed by the same letter, lowercase in the column and uppercase in line do not differ statistically by Scott-Knott test at 10% of probability.

Table 5. Test of mean grouping for the variable plant height (PH) with different number of applications of insecticide

	Plant height (m)						
	1 Application[1]		2 Applications[1]		3 Applications[1]		Mean
Celeron	2.233	b	2.177	b	2.263	a	2.224
Celeron TL	2.313	a	2.240	a	2.363	a	2.306
Formula	2.220	b	2.117	b	2.203	b	2.180
Formula TL	2.223	b	2.237	a	2.220	b	2.227
Ag9010	1.883	d	1.893	d	1.933	d	1.903
Ag9010 YG	1.927	d	1.880	d	1.927	d	1.911
Sprint	2.087	c	2.030	c	2.143	b	2.087
Sprint TL	1.983	d	1.917	d	2.063	c	1.988
Impacto	2.287	a	2.183	b	2.210	b	2.227
Impacto TL	2.243	b	2.170	b	2.243	b	2.219
Dkb390	2.147	b	2.143	b	2.190	b	2.160
Dkb390 YG	2.110	c	2.073	b	2.180	b	2.121
Penta	2.210	b	2.117	b	2.167	b	2.164
Penta TL	2.283	a	2.250	a	2.217	b	2.250
Status	2.380	a	2.267	a	2.320	a	2.322
Status TL	2.337	a	2.243	a	2.270	a	2.283
Mean[2]	2.179	A	2.121	B	2.182	A	

[1,2] *Means followed by the same letter, lowercase in column and uppercase in line, do not differ statistically by Scott-Knott test at 10% probability.*

in the first group in this variable. With lower plant height, hybrids AG9010 and AG9010 YG were in the last group in the three levels of application of insecticide. For this variable, the means of application did not present the same behavior in relation to grain yield, considering that for plant height the means of 1 to 3 applications had superior average in relation to 2 applications.

Table 6 presents data for height of ear insertion for the different hybrids evaluated in relation to the variation of the number of application of insecticide, in the cultivation of the maize “off-season”.

For height of ear insertion (Table 6), three hybrids were classified in the first group in the three levels of application of insecticide IMPACTO, IMPACTO TL and STATUS TL, in relation to the mean, testing the efficiency of the application, the levels of 1 and 3 applications presented higher values, which put them in the first group, in relation to 2 application which was in the second group.

Plant height and ear insertion are factors which do not suffer great ranges for the same cultivar tested in the same place, over the same climate and soil conditions, according to SOUZA et al. (2001).

Considering that plant height and ear insertion present positive correlation as plant lodging and tumbling, these characteristics with high values may be considered undesirable (ARAÚJO, 1992). Thus, with these considerations, hybrids AG9010 e AG9010 YG are noteworthy with lower values of plant height in the three levels of application, and for height of ear insertion hybrids AG9010, AG9010 YG and SPRINT TL are noteworthy in the same way being always in the last group by the test of mean grouping.

Other factor which should be emphasized is the existence of positive correlation between grain yield, plant height and ear insertion (WERLE, 2011), which indicates that higher hybrids with higher ear insertion present a tendency of higher grain yield. Thus, this characteristic should be evaluated together with other characteristics as rooting and stem structure of the evaluated hybrids, since plant height and ear insertion are determinant for plant tumbling and lodging, and are also associated with other characteristics.

In Figure 1 it is presented the tests of mean grouping applied in the hybrids testing the influence of the application of the insecticides, as well as the overall averages of the different hybrids. In this graphic, it can be noticed that hybrids suffered positive influence of the application of insecticides, considering that the highest influence was suffered by the hybrid CELERON, with three applications of insecticide. This hybrid was noteworthy, but the same did not happen when it was performed one or

Table 6. Test of mean grouping for the average height of insertion of ear with different number of application of insecticide.

	Height of ear insertion						
Hybrids	1 Application[1]		2 Application s[1]		3 Application s[1]		Mean
Celeron	1.017	c	0.933	b	1.117	b	1.022
Celeron TL	1.017	c	0.933	b	0.950	c	0.967
Formula	1.100	c	0.867	b	0.983	c	0.983
Formula TL	0.900	d	0.817	b	1.083	b	0.933
Ag9010	0.900	d	0.933	b	0.900	c	0.911
Ag9010 YG	0.900	d	0.900	b	0.867	c	0.889
Sprint	1.017	c	0.983	b	1.083	b	1.028
Sprint TL	0.900	d	0.783	b	1.033	c	0.906
Impacto	1.317	a	1.167	a	1.200	a	1.228
Impacto TL	1.317	a	1.217	a	1.267	a	1.267
Dkb390	1.200	b	1.100	a	1.233	a	1.178
Dkb390 YG	1.167	b	1.100	a	1.150	b	1.139
Penta	1.067	c	1.100	a	1.200	a	1.122
Penta TL	1.133	b	1.083	a	1.100	b	1.106
Status	1.233	b	1.183	a	1.217	a	1.211
Status TL	1.300	a	1.283	a	1.300	a	1.294
Mean[2]	1.093	A	1.024	B	1.105	A	

[1,2] Means followed by the same letter, lowercase in the column and uppercase in line do not differ statistically by Scott-Knott test at 10% of probability.

two applications of insecticide. The explanation of this result may be the high infestation of aphids in this hybrid. In the third application, the insecticide controlled the attack of this kind of plague, fact which should also be related to the increase of yield with three applications in *Bt* hybrids. In relation to the overall mean yield with different numbers of applications of insecticide the hybrid IMPACTO TL was noteworthy in the experiment, with yield superior to 6000 kg ha^{-1}, in this experiment.

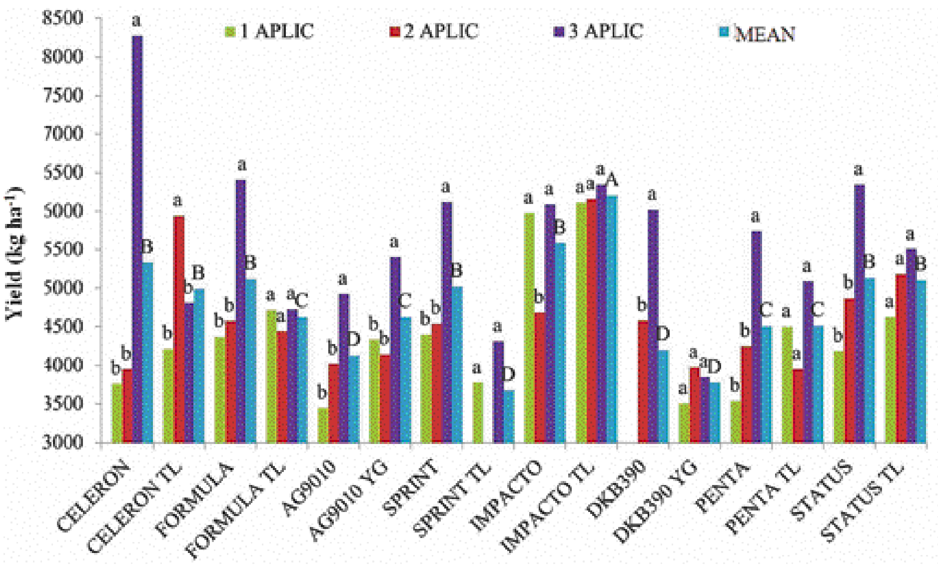

Figure 1. Test of means in each hybrid evaluating the influence of the insecticide.

Conclusions

The different hybrids used present potential for use in off-season for the region of Cascavel;

Hybrids presented different responses according to the number of applications of the insecticide;

With one application of insecticide the planting of hybrids *Bt* presented higher viability, however with 3 applications it is more viable the cultivation of hybrids which are not *Bt*;

In an overall mean, the hybrid IMPACTO TL presented higher productive potential;

Individually the highest yield was obtained by the hybrid CELERON with the applications of insecticide.

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