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SEEDLING GROWTH OF MAIZE (*ZEA MAYS* L.) INBRED LINES AFFECTED BY SEED TREATMENT WITH PESTICIDES

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Abstract: Seed treatment is a common way of fungicide and insecticide use nowadays, since this way of pesticide application can provide the best protection in the vicinity of the future plant. The aim of research was to evaluate the effects of different seed treatments on germination and seedling growth in three maize inbred lines. The research included the seed treatment with several combinations of a fungicide Maxim XL 035-FS (a.i. metalaxil-M + fludioxonil) and neonicotinoid insecticides Gaucho 600-FS (a.i. imidacloprid) and Cruiser 350-FS (a.i. thiamethoxam), as well as untreated seed (control). The results indicated that inbred lines 21202 x 21101 NS and 317659 NS had a highly vigourous seed which was not affected by the seed treatments. The seed treatments with Maxim XL 035-FS+Gaucho 600-FS and Maxim XL 035-FS+Cruiser 350-FS led to a decrease in germination (90.25% and 89.50%, respectively) of maize inbred line 306081 NS as well as a decrease in root length (126.75 mm and 125.25 mm, respectively) and dry root weight (0.135 g and 0.1875 g, respectively) of maize inbred line 21202 x 21101 NS. All seed treatments had positive effects on root growth, as well as on fresh root weight of maize inbred lines 306081 NS and 317659 NS.

Key words: seed treatments with fungicide and insecticides, maize inbred lines, germination, growth parameters.

Introduction

Production of a high quality seed of maize inbred lines is the basic requirement for successful maize (*Zea mays* L.) seed production. Given that maize inbred lines are more affected by biotic and abiotic stresses, adequate protection has great importance for successful seed production.

Application of chemicals, such as the seed treatment with fungicides is perhaps the most effective measure for integrated crop protection, making it a legal

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obligation for all seed producers in Serbia (Stevanović et al., 2009). The seed treatment with insecticides is a more environmentally friendly method of insecticide application (Bača et al., 2008), and can provide direct economic benefits by reducing both chemical and application costs (Stevens et al., 2008). Seed treatment also has its disadvantages, such as increased risk of phytotoxicity. Stevens et al. (2008) have stated that seeds treated with pesticides are often exposed to significantly higher chemical concentrations than in foliar treatments. However, it has been reported that some fungicides and insecticides could act as suppressors or stimulators of germination (Stevanović et al., 2009; Dragičević et al., 2011). Thiamethoxam may promote changes in certain processes in plant physiology, such as growth, biomass accumulation, increased height and flowering, and increased seed vigour (Almeida et al., 2013; Castro and Pereira, 2008; Van Tol and Lentz, 1999; Cataneo et al., 2010). Moreover, it is observed that thiamethoxam seed treatment had no effect on germination and plant growth of soybean (Castro et al., 2008). Imidacloprid has been evaluated as a seed treatment without any phytotoxicity (Pike et al., 1993; Wilde et al., 2001; Stevens et al., 2008). Conversely, Dan et al. (2012) observed a reduction in dry matter accumulation of soybean plants when treated with imidacloprid. These various results suggested that it would be beneficial to examine the effect of different seed treatments, since maize inbred lines are more sensitive and vulnerable than maize hybrids.

The objective of this research was to evaluate the effect of seed treatment with a fungicide and insecticides on germination and initial growth of three maize inbred lines.

Material and Methods

The experiment was conducted at the Laboratory for Seed Testing, Institute of Field and Vegetable Crops, Novi Sad. Maize inbred lines 21202 x 21101 NS, 306081 NS, and 317659 NS used in this study were developed at the Institute of Field and Vegetable Crops, Novi Sad. Seeds were treated with commercial formulations Maxim XL 035-FS, Maxim XL 035-FS + Gaucho 600-FS, and Maxim XL 035-FS + Cruiser 350-FS at recommended doses (Table 1).

Table 1. Pesticide commercial formulations and basic properties of pesticides.

Pesticide commercial formulation	Manufacturer	Active ingredient (g/l)	Chemical group	Application rate (ml/100 kg)	Range of action
Gaucho 600-FS	Bayer Crop Science, Germany	Imidacloprid (600)	Neonicotionid	600	Soil pests
Cruiser 350-FS	Syngenta Crop Protection, Switzerland	Thiamethoxam (350)	Neonicotionid	900	
Maxim XL 035-FS	Syngenta Crop Protection, Switzerland	Metalaxil-M+fludioxonil (10+25)	Acylalanines + phenylpyroles*	100	*Fusarium spp. Phytium spp*.

The standard germination test

A working sample consisted of 4 x 100 seeds randomly selected. Sterile sand was used as substrate. Seeds were incubated in the germination chamber at 25°C for a period of seven days (ISTA 2014). Seed germination (%) and abnormal seedlings (%) were determined seven days after sowing. Ten typical seedlings of each replicate were taken for measurement of seedling growth parameters. Seedling growth parameters, shoot length, and root length were measured seven days after sowing, as well as shoot and root fresh weights. After measuring fresh shoot and root weights of seedlings, the samples were dried in the oven at 80°C for 24 hours, and shoot and root dry weights of seedlings were determined.

Statistical Analysis

The obtained results were statistically processed, using analysis of variance (One Way ANOVA) and software Statistica 12 (StatSoft, Inc., 2015). The significance of the obtained differences between treatments was determinated by Duncan's multiple range test, at the significance level of 5% ($P<0.05$).

Results and Discussion

Although maize inbred line 21202 x 21101 NS did not show significant differences in the germination percentage and abnormal seedling percentage ($P<0.05$), seed treatments affected growth parameters of the seedlings (Table 2). All seed treatments led to an increase in shoot length compared to control. Seed treatments with Maxim XL 035-FS + Gaucho 600-FS and Maxim XL 035-FS + Cruiser 350-FS reduced root length of seedlings (126.750 mm and 125.250 mm, respectively). The reduction of root length of inbred line 21202 x 21101 NS treated with Maxim XL 035-FS + Gaucho 600-FS was in accordance to the results achieved on cucumber and reported by Ebel et al. (2000), who noted that the use of imidacloprid reduced the growth of the whole plant, decreased the root system, and altered mineral nutrition. Conversely, imidacloprid has been evaluated as a seed treatment without any phytotoxicity or adverse effects on plant growth of wheat, barley, and forage brassicas (Pike et al., 1993; Wilde et al., 2001; Stevens et al., 2008). All seed treatments resulted in significantly higher shoot fresh and dry weights than control, with the exception of treatment with Maxim XL-035 FS + Cruiser 350-FS on shoot dry weight. Fresh root weight was significantly increased in Maxim XL-035 FS and Maxim XL-035 FS + Cruiser 350-FS treatments, and significantly decreased in Maxim XL-035 FS + Gaucho 600-FS treatment, while root dry weight significantly decreased after treatments with Maxim XL-035 FS + Gaucho 600-FS and Maxim XL-035 FS + Cruiser 350-FS compared to control.

Dragičević et al. (2011) observed an increase in fresh matter on the shoot and root levels of maize inbred lines treated with fludioxonil + metalaxil–M and imidacloprid, and fludioxonil + metalaxil–M and thiamethoxam. The results obtained by Cataneo (2008) and Alemida et al. (2013) showed positive effects of thiamethoxam on biomass accumulation, high photosynthetic rate and deeper roots. Inđić et al. (2008) stated that thiamethoxam-based formulations reduced shoot dry matter content in oilseed pumpkin, contrary to the results obtained in the present research.

Table 2. The effects of the seed treatment with pesticides on seed germination and seedling growth in maize inbred line 21202 x 21101 NS.

Maize inbred line 21202 x 21101 NS	Seed treatment				p values
	Control	Maxim XL 035-FS	Maxim XL 035-FS + Gaucho 600-FS	Maxim XL 035-FS + Cruiser 350-FS	
Germination (%)	99.00 a	97.50 a	97.00 a	97.75 a	0.174
Abnormal seedlings (%)	0.75 a	2.00 a	1.00 a	1.00 a	0.366
Shoot length (mm)	146.500 d	168.625 b	183.000 a	155.875 c	0.000
Root length (mm)	155.500 a	156.375 a	126.750 b	125.250 b	0.000
Fresh shoot weight (g)	5.7425 b	6.2925 a	6.5225 a	6.5400 a	0.001
Fresh root weight (g)	2.1375 b	2.7925 a	1.5200 c	2.7475 a	0.000
Dry shoot weight (g)	0.2475 b	0.3575 a	0.3375 a	0.2550 b	0.001
Dry root weight (g)	0.2400 a	0.2200 a	0.1350 c	0.1875 b	0.000

All seed treatments significantly reduced seed germination and significantly increased the percentage of abnormal seedlings in maize inbred line 306081 NS compared to control (Table 3). It has been reported that seed treatments with imidacloprid may result in decreased germination and increased abnormal seedlings (Kuhar et al., 2002; Taylor et al., 2001). Stevens et al. (2008) also noted that imidacloprid seed treatment adversely affected germination of several crops. However, Kuhar et al. (2002) stated that highly vigourous seed lots were more tolerant to imidacloprid treatment, which was also confirmed in this study. The greatest shoot length was recorded in treatment with Maxim XL-035 FS + Cruiser

350-FS (143.25 mm) and it was significantly greater than in treatments with Maxim XL-035 FS and Maxim XL-035 FS + Gaucho 600-FS. All seed treatments increased root length compared to control. It has been assessed that the treatment with thiamethoxam produces plants with greater root growth and higher growth of the aerial part (Nunes, 2006; Dan et al., 2012). With regard to this, Castro and Pereira (2008) have found that thiamethoxam has the capability of inducing physiological changes in a plant. It can increase mineral nutrition of the plant, which promotes positive responses in plant development and productivity. It also results in higher enzymatic activity caused by thiamethoxam, which increases both primary and secondary metabolism, due to the fact that some treatments such as thiamethoxam might have an activating effect, thus increasing the size of roots and shoots (Almeida et al., 2013). Fresh and dry weights of root and shoot in treatment with Maxim XL-035 FS were significantly higher compared to other treatments and control. These results are in accordance with the results obtained in sunflower studies and reported by Mrđa et al. (2011).

Table 3. The effects of the seed treatment with pesticides on seed germination and seedling growth in maize inbred line 306081 NS.

Maize inbred line 306081 NS	Seed treatment				p values
	Control	Maxim XL 035-FS	Maxim XL 035-FS + Gaucho 600-FS	Maxim XL 035-FS + Cruiser 350-FS	
Germination (%)	97.00 a	93.00 b	90.25 c	89.50 c	0.000
Abnormal seedlings (%)	1.75 b	4.00 a	2.00 a	8.50 a	0.002
Shoot length (mm)	134.000 ab	123.000 b	121.000 b	143.250 a	0.120
Root length (mm)	105.000 c	155.125 a	160.625 a	124.375 b	0.000
Fresh shoot weight (g)	3.9125 d	5.7000 a	4.7600 c	5.1050 b	0.000
Fresh root weight (g)	1.6675 c	2.8200 a	2.1450 b	2.1580 b	0.000
Dry shoot weight (g)	0.3025 c	0.3975 a	0.2775 c	0.3575 b	0.000
Dry root weight (g)	0.1950 b	0.3000 a	0.1875 b	0.2025 b	0.000

There were neither significant effects of seed treatments on germination nor abnormal seedlings in maize inbred line 317659 NS (Table 4). Macedo and Castro (2011) observed no changes in germination and growth of shoots and roots of soybean plants treated with thiamethoxam. However, positive effects of thiamethoxam on germination of rice were presented by Almeida et al. (2013), contrary to the results of the present research obtained for maize inbred line 317659 NS treated with Maxim XL-035 FS + Cruiser 350-FS. The seed treatment with Maxim XL-035 FS + Gaucho 600-FS and Maxim XL-035 FS + Cruiser 350-FS reduced shoot length. A significant increase in root length and fresh root weight was observed in all seed treatments compared to control. The seed treatment with Maxim XL-035 FS + Gaucho 600-FS led to a significant decrease in shoot fresh weight compared to control and Maxim XL-035 FS + Cruiser 350-FS treatment. The highest root and shoot dry weights were recorded after treatment with Maxim XL-035 FS (0.38 g and 0.24 g, respectively), and these results were significantly higher than in control and treatment with Maxim XL-035 FS + Gaucho 600-FS. Only the seed treatment with Maxim XL-035 FS significantly increased dry shoot weight in all tested inbred lines, which is in accordance with the results obtained by Dragičević et al. (2011).

Table 4. The effect of the seed treatment with pesticides on seed germination and seedling growth in maize inbred line 317659 NS.

Maize inbred line 317659 NS	Seed treatment				p values
	Control	Maxim XL 035-FS	Maxim XL 035-FS + Gaucho 600-FS	Maxim XL 035-FS + Cruiser 350-FS	
Germination (%)	97.50 a	96.75 a	97.25 a	97.75 a	0.592
Abnormal seedlings (%)	1.00 a	2.25 a	1.50 a	1.75 a	0.410
Shoot length (mm)	158.625 a	148.125 ab	140.375 bc	136.125 c	0.004
Root length (mm)	120.750 b	148.125 a	153.500 a	150.750 a	0.000
Fresh shoot weight (g)	5.595 ab	5.315 bc	4.985 c	5.9225 a	0.000
Fresh root weight (g)	0.7700 c	2.365 b	2.3325 b	2.9225 a	0.000
Dry shoot weight (g)	0.3375 bc	0.3750 a	0.3075 c	0.3600 ab	0.004
Dry root weight (g)	0.0975 b	0.2350 a	0.2250 b	0.2650 a	0.000

Conclusion

Based on the obtained results, it can be concluded that the seed treatments had positive effects on shoot growth of maize inbred line 21202 x 21101 NS. Maize inbred lines 21202 x 21101 NS and 317659 NS can be considered as resistant since the seed treatments did not adversely affect seed germination or cause the occurrence of abnormal seedlings. Moreover, it can be concluded that the treatments had a positive impact on root growth and biomass accumulation of maize inbred lines 306081 NS and 317659 NS.

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PORAST IZDANAKA INBRED LINIJA KUKURUZA (*ZEA MAYS* L.) POD UTICAJEM TRETMANA SEMENA PESTICIDIMA

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R e z i m e

Tretiranje semena fungicidima i insekticidima je uobičajen način pripreme semena pre setve, s obzirom na to da ovaj način primene pesticida može da pruži najbolju zaštitu mlade biljke od patogena i štetočina u zemljištu. Cilj ovog istraživanja bio je da se ispita uticaj različitih tretmana semena pesticidima na klijanje semena i početni porast izdanaka različitih inbred linija kukuruza. Istraživanje je obuhvatilo testiranje tretmana semena inbred linija kukuruza sa nekoliko kombinacija fungicida (Maxim XL 035-FS, fludioksonil, 25 g/l + metalaksil-M, 10 g/l) i insekticida (Gaucho 600-FS, imidakloprid 600 g/l i Cruiser 350-FS, tiametoksam, 350 g/l). Netretirano seme je uzeto za kontrolu. Rezultati istraživanja su pokazali da inbred linije 21202 x 21101 NS i 317659 NS imaju visoko vigorozno seme, na koje nisu uticali testirani preparati. Testirane kombinacije preparata pesticida Maxim XL 035-FS+Gaucho 600-FS i Maxim XL 035-FS+Cruiser 350-FS dovele su do smanjenja klijavosti semena inbred linije 306081 NS (90,25%, odnosno 89,50%), kao i do smanjenja dužine korena (126,75 mm, odnosno 125,25 mm) i mase suvog korena (0,135 g, odnosno 0,1875 g) izdanaka inbred linije 21202 x 21101 NS. Svi testirani tretmani imali su pozitivan uticaj na porast korena izdanaka, kao i na masu svežeg korena izdanaka inbred linija 306081 NS i 317659 NS.

Ključne reči: tretiranje semena fungicidima i insekticidima, inbred linije kukuruza, klijavost semena, parametri porasta izdanka.

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