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Short Paper

Utility of fungicides for controlling *Rhizoctonia solani* on sugar beet

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Abstract: *Rhizoctonia solani* is the most serious problem on sugar beet *Beta vulgaris* L. grown in North Dakota and Minnesota. Picoxystrobin, a quinone outside inhibitor, and penthiopyrad, a succinate dehydrogenase inhibitor, were used alone and in combinations for controlling *R. solani* AG 2-2 IIIB on sugar beet under greenhouse conditions of 22 ± 2 °C and a 12-h photoperiod. Fungicides were applied in-furrow at planting, followed by inoculation with *R. solani* grown on barley seeds. The experimental design was a randomized complete block with four replicates and the experiment was repeated three times. Stand counts were taken and roots were evaluated for symptoms using a 0 to 7 scale 21 days after inoculation. Analysis of variance was conducted by the SAS general linear model, and Fisher's protected least significant difference at $\alpha = 0.05$ was used to compare treatment means. Fungicides used alone and in mixtures provided effective control of *R. solani*, which had significantly greater percent survivors than the inoculated check. This research demonstrated that picoxystrobin and penthiopyrad have the potential to be used for providing control of *R. solani* on sugar beet.

Keywords: Rhizoctonia root rot, sugar beet, picoxystrobin, penthiopyrad, *Rhizoctonia solani*

Introduction

Rhizoctonia solani is a common soil-borne fungus that causes damping-off, and crown and root rot on sugar beet worldwide (Ayala *et al*., 2001; Harveson *et al*., 2009; Herr, 1996). The pathogen is divided into anastomosis groups (AGs) and further subdivided into intra specific groups (ISGs). The main subgroup reported on sugar beet in Europe is AG 2-2 IIIB whereas AG 2-2 IIIB and AG 2-2 IV are more common in the United States (Windels and Nabben, 1989). North Dakota and Minnesota produce about 57% of the US sugar beet and since the mid-1990s, *R. solani* has been increasing in prevalence and severity in these states (Brantner and Windels, 2007; Khan *et al*., 2005). Disease severity varies based on field histories with reports of yield losses higher than 50% resulting in field destruction, as well as in non-treated checks in inoculated field trials (Khan *et al*., 2010; Windels and Brantner, 2005).

Rhizoctonia crown and root rot on sugar beet caused by *R. solani* is managed by using a combination of partially resistant cultivars, agronomic practices, and the use of fungicides is common in the United States but not in Europe (Buhre *et al*., 2009). Resistant cultivars typically have significantly lower potential yield than susceptible commercial cultivars (Panella and Ruppel, 1996). Agronomic practices include improved field drainage, early planting in cool soils, crop rotation with wheat and barley, and avoidance of hilling soil into crown of sugar beet. Azoxystrobin (Quadris® Syngenta; Greensboro, NC, USA), a quinone outside inhibitor (QoI)

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fungicide, is the most widely used fungicide for controlling *R. solani* in the United States since it was registered in 1999 (Carlson *et al*., 2012; Khan *et al*., 2010).

In the United States, *R. solani* isolates resistant to azoxystrobin was first reported on rice, which has raised increased concerns about fungicide resistance management (Olaya *et al*., 2012). Picoxystrobin (Aproach®, DuPont, Wilmington, DE, USA), a QoI fungicide, is labeled for use on canola, cereal grains, corn, and soybeans to control foliar and soil-borne diseases but is not labeled for use on sugar beet. Penthiopyrad (Vertisan®, DuPont), a succinate dehydrogenase inhibitor (SDHI) fungicide, was registered for use on sugar beet for controlling *R. solani* in 2012. The use of an effective SDHI fungicide or a combination of two fungicides with different modes of action may help delay the development of fungicide resistant isolates (van den Bosch *et al*., 2014).

The objective of this greenhouse study was to evaluate the efficacy of picoxystrobin and penthiopyrad individually and as mixtures for controlling *R. solani* on sugar beet.

Materials and Methods

Trials were conducted in a greenhouse at North Dakota State University, Fargo, North Dakota, USA. Plastic trays measuring 27 x 13 x 13 cm tray (T.O. Plastics, Inc.; Clearwater, MN, USA) were filled with sunshine mix # 1 peat (Sun Gro Horticulture Inc; Alberta, Canada). Ten sugar beet seeds of cultivar Crystal 539RR, susceptible to *R. solani* (Niehaus, 2011) were planted into 2.5-cm-deep furrows made in the center of each tray. Fungicide treatments were made directly into the furrow followed by inoculation with *R. solani* AG 2-2 IIIB infested barley grains, one grain 1-cm away from each seed (Noor and Khan, 2014). For the inoculated check, *R. solani* infested barley grains were placed by the sugar beet seeds and for the non-inoculated check, sterilized barley grain, but with no *R. solani*, were placed by the seeds. The furrows were covered with sunshine mix #1 peat, compacted and watered. Greenhouse conditions were set at 12-h photoperiod and temperature ranged from 22 ± 2 ^{o}C and sugar beet plants were watered daily to maintain adequate soil moisture favorable for plant growth and disease development. Seedling and plants were observed for abnormal growth, stunting, leaf curl and mottling. Twenty-one days after inoculation, stand counts were taken and plants were carefully removed from trays after saturating the potting mix. The roots were washed under tap water and evaluated for symptoms using a 0 to 7 scale: 0 (no disease), 1 (crown area slightly scurfy), 2 (< 5% infection), 3 (6 - 25% infection), 4 (26 - 50% infection), 5 (51 - 75% infection), 6 (> 75% infection), and 7 (the root completely deteriorated or dead plant) (Windels and Nabben-Schindler, 1996). To confirm that the symptoms were caused by *R. solani* the fungus was re-isolated from infected plants by plating small pieces of the infected roots on water agar media (Butler, 1957).

The seven treatments evaluated included picoxystrobin (Aproach™, 22.5% a.i., DuPont) used alone at 564 g a.i./ha; penthiopyrad (Vertisan™, 20.6% a.i., DuPont) used alone at 555 g a.i./ha; and picoxystrobin: penthiopyrad mixtures of 273: 290; 419: 409; and 564: 555 g a.i./ha; inoculated check; and a non-inoculated check treated with sterilized barley grain. Treatments were applied using a Generation III Research Sprayer (Devries Manufacturing Hollandaise, MN) calibrated to spray fungicides at 138 kPal with a speed of 6 kph using a single flat fan nozzle (4001E).

The experimental design was a randomized complete block with four replicates. The experiment was repeated three times. The experiments were analyzed separately using analysis of variances. Bartlett's chi-square test was performed on the variances to test for homogeneity among experiments. Analysis of variance was conducted by the SAS general linear model (Proc GLM) procedure (Version 9.3, SAS Institute Inc.; Cary, NC, USA). Fisher's protected least significant difference (LSD) at $\alpha = 0.05$ was used to compare treatment means.

Results

The calculated *P*-value ($\chi^2 = 0.448$, $P = 0.7995$) in Bartlett's test was not statistically significant, therefore the data from the repeated experiment were combined. There were significant differences among treatments at $P \leq 0.05$ level of confidence.

The non-inoculated check had the highest percent (88%) of survivors which was significantly greater than the percent survivors in the inoculated check (8%). The high mortality in the inoculated check confirmed that the inoculum was effective at killing seedlings and young plants (Table 1). All the fungicide treatments resulted in significantly greater percent of survivors compared to the inoculated check. Picoxystrobin used alone resulted in similar levels of survivors as penthiopyrad used alone and there were no significant differences in percent survivors between the different rates of mixtures of picoxystrobin and penthiopyrad and when these products were used individually. However, the picoxystrobin and penthiopyrad mixture with the highest rate of each product resulted in 80% survival which was the only treatment that was statistically similar to the non-inoculated check (88%). All the roots of plants where the seeds received fungicide treatments were without symptoms. Likewise there were no visual symptoms of plant injury (phytotoxicity) on the plants treated at the seed stage with fungicides compared to the non-inoculated check.

Table 1 Effect of picoxystrobin and penthiopyrad used individually and in mixtures at controlling *Rhizoctonia solani* AG 2-2 IIIB on sugar beet in sunshine mix # 1 peat in greenhouse.

Treatments (active ingredient / ha)	Plant survivors (%)[1]
Non-inoculated check	88
Inoculated check	8
Picoxystrobin at 565 g	73
Penthiopyrad at 555 g	73
Picoxystrobin and Penthiopyrad at 273: 290 g	75
Picoxystrobin and Penthiopyrad at 419: 409 g	74
Picoxystrobin and Penthiopyrad at 565: 555 g	80
LSD (P = 0.05)	10

[1] Plants were kept at 22 ± 2 °C and a 12-h day length. There were four replicates per treatment and the experiment was repeated three times. The data below were from combined experiments.

Discussion

This greenhouse study demonstrated that all the rates of the fungicides used alone and in mixtures when applied in-furrow at planting provided control of *R. solani*. There were no symptoms of damping-off or root rot which suggested that the fungicides applied at planting prevented *R. solani* from causing infection. However, the combination of picoxystrobin and penthiopyrad with the highest rate of each was the only treatment which resulted in statistically similar percent survivors as the non-inoculated check. We did not find any peer reviewed journal articles where picoxystrobin was used for controlling *R. solani* on sugar beet. Likewise, there was no peer reviewed articles on the use of penthiopyrad used as a spray application for control of *R. solani* on sugar beet. Kirk and Schafer (2011) showed that either penthiopyrad at 433 g a.i. ha^{-1} or picoxystrobin at 409 g a.i. ha^{-1} applied in-furrow resulted in significantly reduced disease incidence and severity, and greater marketable beets than the untreated inoculated check. Yanase (2013) indicated that penthiopyrad used as a seed treatment at different rates effectively controlled *R. solani* on sugar beet.

In this study all the fungicide treatments except the highest rates used in the mixture resulted in significantly lower percent of survivors compared to the non-inoculated check. Since the treated plants were all healthy without any symptoms of infection by *R. solani*, it is possible that the reduced percent of survivors, relative to the non-inoculated check, was probably as a result of lower emergence. We did not check to determine whether there were seeds in the potting mix that did not germinate. It should be noted that the presence of non-germinated seeds does not necessarily mean that the fungicide was the cause for non-germination and/or non-emergence since commercial sugar beet seeds typically have 60 to 76% emergence in field studies (Niehaus, 2009).

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Further research should be done in the field to determine the efficacy of picoxystrobin and penthiopyrad alone and in mixtures for controlling *R. solani* and the safety of these fungicides on seeds, seedlings and young sugar beet plants.

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استفاده از قارچ‌کش‌ها برای کنترل *Rhizoctonia solani* روی چغندر قند

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چکیده: قارچ *Rhizoctonia solani* مهم‌ترین مشکل چغندر قند *Beta vulgaris* در داکوتای شمالی و مینسوتا می‌باشد. پیکوکسی استروبین که بازدارنده کینون است و پنتیوپیراد که بازدارنده سوکسینات دهیدروژناز است به‌تنهایی و به‌صورت ترکیبی برای کنترل *R. solani* AG 2-2 IIIB روی چغندر قند در شرایط گلخانه با دمای 2 °C ± 22 و دوره نوری ۱۲ ساعت روشنایی استفاده شد. قارچ‌کش‌ها پس از مایه‌زنی با *R. solani* که روی بذر جو کشت داده شده بود در هنگام کاشت استفاده شد. آزمایش در قالب طرح بلوک کامل تصادفی با چهار تکرار و آزمایش سه بار انجام شد. تعداد بوته‌ها شمارش شد و علایم مربوط به ریشه‌ها ۲۱ روز بعد از مایه‌زنی با امتیازدهی از ۰ تا ۷ ارزیابی شدند. تجزیه واریانس با SAS و مدل خطی عمومی و آزمون فیشر در سطح ۵ درصد برای مقایسه میانگین‌ها انجام شد. قارچ‌کش‌ها به‌تنهایی و به‌صورتی ترکیبی به‌طور مؤثری نسبت به شاهد *R. solani* را کنترل نمود. این پژوهش نشان داد که پیکوکسی استروبین و پنتیوپیراد توانایی کنترل *R. solani* را روی چغندر قند دارد.

واژگان کلیدی: پوسیدگی ریشه رایزوکتونیایی، چغندر قند، picoxystrobin، penthiopyrad، *Rhizoctonia solani*

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