Crop Protection 92 (2017) 190–197

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Effect of spray droplet size, spray volume and fungicide on the control of white mold in soybeans

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ARTICLE INFO

Article history:
Received 21 June 2016
Received in revised form
27 October 2016
Accepted 28 October 2016
Available online 13 November 2016

Keywords:
Sclerotinia sclerotiorum
Glycine max
Spray technology

ABSTRACT

Two experiments were conducted at different locations, the first in the 2012-13 season, and the second in the 2013-14 season, to evaluate the effectiveness of fluazinam and procymidone fungicides applied at volumes of 100 and 200 L ha^{-1}, using three types of nozzles (hollow cone, flat fan, and air induction flat fan) in soybean, for the control of white mold (*Sclerotinia sclerotiorum* Lib. de Bary). This study assessed white mold incidence, severity, sclerotia production and yield. In the 2012–13 crop season experiment, there was no difference between the spray volumes of 100 and 200 L ha^{-1} for any of the white mold assessments. With regard to the nozzles, the use of the air induction flat fan nozzle resulted in lower incidence and production of sclerotia. In the 2013-14 season experiment, the use of the flat fan nozzles, and the air induction flat fan nozzles resulted in the lowest rates of white mold incidence. Procymidone promoted a reduction in sclerotia production in comparison with fluazinam. No differences in yield were detected between the studied factors. Therefore, it was concluded that the spray volume did not influence the control of white mold and the use of air induction nozzle was efficient in controlling white mold in soybeans.

1. Introduction

The cultivation of soybean (*Glycine max* L. Merrill) is of worldwide importance because of its high protein content. Soybean has particularly high economic importance in Brazil, with more than 30 million hectares harvested in the 2014–15 crop season (Conab, 2015). However, many biological factors are responsible for limitations in achieving higher productivity such as pests, weeds and diseases. Among the 40 diseases that occur in soybean in Brazil, white mold (*Sclerotinia sclerotiorum* Lib. De Bary) is among the most damaging (Embrapa, 2013).

This fungus affects 408 species of plants, including crops of major economic importance (Boland and Hall, 1994), and it can cause up to 100% reductions in production in some crops in favorable conditions, causing millions of dollars in losses worldwide (Saharan and Mehta, 2008). In Brazil, it is estimated that the disease is present in over 23% of the soybean area within the country and there are reports that it has reduced productivity in soybean by more than 30% (Meyer et al., 2014; Wutzki et al., 2016).

The pathogen produces resistance structures, called sclerotia, which remain viable in the soil for a period longer than five years, making it difficult to control and eradicate the disease after it has been introduced into growing areas (Steadman, 1983). For this reason, several strategies should be used to manage white mold, such as biological control, improving the row spacing and seeding rate, choosing the correct time of the year for sowing, soil cover, shorter cultivars, and increasing the penetration of light between rows, as well as chemical control (Jaccoud Filho, 2014; Abdullah et al., 2008; Mueller et al., 2001; Peachey et al., 2006).

The chemical control of *S. sclerotiorum* is an important tool; however, its effectiveness lies in the correct time of application, i.e. fungicide should be applied at the beginning of the flowering of the

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http://dx.doi.org/10.1016/j.cropro.2016.10.016
0261-2194/

crop to protect the flowers of the culture before they grow and serve as an inoculum for the initial infection of the disease by the germination of ascospores on the surface of the flowers (Natti, 1971; Mueller et al., 2004).

However, the first flowers in soybean are formed at the bottom of the plant, when the crop canopy already fully covers the ground, which hinders the coverage of the fungicide at the time of application. Consequently, choosing the correct nozzle, and the volume of the application to be used, is of the utmost importance to achieve the maximum penetration of the spray solution in the plant canopy and to protect the first flowers that are formed in the plant.

Thus, the aim of this study was to verify if volume rate and type of nozzle could have an effect in the efficiency of both contact and systemic fungicides regarding the control of white mold in soybean.

2. Materials and methods

Two experiments were conducted in areas naturally infested by white mold, both of them in Paraná State in the south of Brazil. The first was in the 2012–13 crop season in the county of Ivaí in the central-south region of the State of Paraná at an altitude of 934 m above sea level. The second was in the 2013–14 crop season in the county of Mauá da Serra in the north of the State of Paraná at an altitude of 1067 m above sea level.

Prior to the tests being performed, the soil samples were collected in order to quantify the number of sclerotia in the experimental areas at four 0.25 m^2 areas at a depth of 0.05 m. The soil samples were processed in a 2 mm mesh sieve and the number of sclerotia present in each sample was counted. In Ivaí, 32 sclerotia m^{-2} were found, and in Mauá da Serra, 452 sclerotia m^{-2}.

2.1. Ivaí, PR

In Ivaí, the soybean variety used for the 2012–13 crop season was BMX Turbo RR (Brasmax, Cambé, Paraná State, Brazil), which has an indeterminate growth habit. It was sown on 11/25/12 with 14 seeds m^{-1}, with 0.45 m row spacing, planted into oat straw and with a base fertilization of 300 kg ha^{-1} in a formulation of 00:20:20. The variety that was chosen was based on what the farmer of the area was using.

Two applications of fluazinam (Frowncide® - ISK Biosciences Brasil Defensivos Agrícolas Ltda) were performed in the treatments, at a rate of 0.50 kg ai ha^{-1}. One application was applied at the R1 stage of soybean (early flowering) (Fehr and Caviness, 1977) and a second application was performed 10 days after the first. The experimental design was a randomized block design with four replications in a factorial scheme (2 × 3) +1: two spray volumes (100 and 200 L ha^{-1}); three types of nozzles: hollow cone (Jacto JA-2); pre-orifice flat fan nozzle (Jacto ADI 110–02); and air induction flat fan nozzle (Teejet AI 110–02), as well as a treatment that did not receive fungicide (Control). The applications are listed in Table 1.

The spray volumes of 100 and 200 L ha^{-1} were chosen due to the fact that the experiments were conducted in southern Brazil. Most soybean producers in that region use spray volumes between 100 and 150 L ha^{-1}. In order to verify whether increasing this spray volume would mean that producers would be better able to control white mold it was decided to test the volume of 200 L ha^{-1}. Spray volume higher than 200 L ha^{-1} were not tested because this was the maximum spray volume that a soy producer in Paraná would be able to use that would be beneficial. Spray volumes such as 300 L ha^{-1} are not viable because producers would rather lose a little effectiveness in the product and improve the logistics of spraying.

Frowncide® is formulated in a suspension concentrate with 500 g L^{-1} active fluazinam. This contact fungicide has no transport in the xylem or phloem, with low mobility at the absorption of the plant. It belongs to the group of phenol-pyridinyl amides, which act in the interruption of oxidative phosphorylation with a protective action, but it does not act curatively or systemically (Gasztonyi and Lyr, 1995).

The spray quality was also evaluated by using 76 mm × 26 mm Teejet® water-sensitive paper in the last spray of the experiment. These cards are made from glossy paper, which is treated with blue bromophenol, a dye that is sensitive to water. This dye is yellow when dry and contact with water droplets produces blue spots (Turner and Huntington, 1970).

Cards were placed in the canopy on metal rods with three holders, where the cards were fixed. These holders had height adjustments to position the water-sensitive paper at a height that was equivalent to the lower, middle and upper thirds of the canopy of the soybean cultivar. There were six rows of soybean in the useful area of each plot and the metal rods with the water-sensitive paper were put in the row space between the second and third row of the soybean plants in the plot.

Soon after the application of the treatment, the cards were quickly removed and placed in a styrofoam box to be taken to the laboratory; this was done to keep them from being exposed to moisture. In the laboratory, the papers were scanned in a table scanner with a resolution of 600 dpi. After scanning, the images were processed using the e-Sprinkle® software, which was developed by Ablevision®, to obtain the results of the percentage of the covered area.

The evaluation of the percentage of the area covered by the spray was chosen because it was the assessment that best represents the amount of product that actually reached the target. In the case of the evaluation of the density of droplets cm^{-2} there nozzles that may have 30 droplets cm^{-2} and reach only 5% of the area covered by the spray solution, whereas other nozzles may have a density of only 20 droplets cm^{-2} and reach 10% of the covered area, thereby providing more spray solution on the target.

2.2. Mauá da Serra, PR

The soybean cultivar used in Mauá da Serra was FTS Ibyara RR (FT Sementes, Ponta Grossa, Paraná State, Brazil), which has a determinate growth habit. It was sown on 10/29/2013 with 12 seeds m^{-1} directly into oat straw, with 0.45 m row spacing and a basic fertilization of 220 kg ha^{-1} in a formulation of 10:44:00 and topdressing of 150 kg ha^{-1} of KCl. The variety that was chosen was based on what the farmer of the area was using.

Two applications of fungicide were applied in the treatments, one at the R1 stage of soybean (early flowering) (Fehr and Caviness, 1977) and a second application ten days after the first. The experimental design was a randomized block design with four replications in a trifactorial scheme (2 × 2 × 3) +1. Two fungicides were used, fluazinam 0.50 kg ai ha^{-1} (Frowncide® - ISK Biosciences Brasil Defensivos Agrícolas Ltda) and procymidone 0.50 kg ai ha^{-1} (Sumilex® - Sumitomo Chemical do Brasil Representações Ltda.), with two spray volumes (100 and 200 L ha^{-1}), three types of nozzles - hollow cone (Jacto JA-2), standard flat fan nozzle (Magno BD 110–02) and air induction flat fan nozzle (Teejet AI 110–02) - as well as a treatment that did not receive fungicide spraying (Control). The meteorological conditions for each application are listed in Table 2.

Based on the results obtained in the first year of study regarding the use of fluazinam with two different volumes and three different spray nozzles, it was decided to include a systemic fungicide (procymidone). Procymidone was included in the study to try to understand if the recommended spray nozzle and spray volume