EXPLORING THE EFFICACY OF FUNGICIDES IN CONTROL OF PEANUT SMUT

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Abstract

Peanut smut, caused by *Thecaphora frezii*, increased its incidence and prevalence in the main

growing region of Argentina in the last decade becoming the main peanut disease. Despite this

fact, growers continue producing peanut without any disease management strategy what is

leading to a local accumulation of *T. frezii* inoculum. The goal of the present study is to assess

the efficacy of fungicide active ingredients for controlling *T. frezii*. We tested 12 fungicides

from different chemical groups in agar plates assays, pots and field experiments during two

growing seasons. Thiophanate-methyl resulted not fungitoxic to *T. frezii* ($EC_{50} > 100$),

mancozeb was moderately fungitoxic ($EC50 = 6.28$), and the rest of the active ingredients were

classified as highly fungitoxic ($EC_{50} < 0.1$). We observed variability in the control efficacy

however azoxystrobin showed the highest control levels in pots experiment 58.9% (2014/15)

and 92% (2015/16). In field experiment, the greatest control efficiency was observed for

cyproconazole in 2015 and azoxystrobin in 2016, reducing peanut smut by 47.7 and 39.5%

respectively. The results obtained in this work can be considered as an effective technique for

30   the integrative smut management strategy, in addition to peanut genetic resistance and cultural

31   practices.

32

33   Key Words: *Thecaphora frezii*; Chemical control; *in vitro* sensitivity; peanut disease; active

34   ingredients

35

36   **1. Introduction**

37   Peanut (*Arachis hypogaea* L.) is an annual extensive crop, with its center of origin in

38   northwestern Argentina and southeastern Bolivia (Hammons, 1982). Argentina produces a

39   high-quality peanut in an area of 350,000 has, concentrating more than 90% in the province of

40   Córdoba located at the center region of the country. More than 95% of the peanut production is

41   exported, previously processed in situ by the industry established in the same growing region

42   (Agüero, 2017; Calzada and Rozadilla, 2018).

43   Peanut smut, caused by the soil-borne fungi *Thecaphora frezii* Carranza and Lindquist,

44   is an endemic and yield reducing disease for the argentine main growing region (Marinelli et

45   al., 2008; 2010; Oddino et al., 2007; Rago et al., 2014). The pathogen is a biotrophic fungi that

46   produces sorus consisting of a powdery mass of spores which colonize seed tissue partially or

47   totally, with potential total damage of the plant pods (Astiz Gasso et al., 2008). The infection

48   process occurs during the crop pegging time: the process in which the flower gynophore

49   penetrates the soil surface, releasing an exudate that stimulate the spore germination Marinelli

50   et al., 2008).

51   Currently, no management strategies for reducing *T. frezii* infections are adopted by

52   argentine growers, which is leading to inter-annual inoculum accumulation (Paredes et al.,

53   2017). Granoleico peanut cultivar (known susceptibility to the smut) is planted in more than

54   80% of the growing region (Rago et al., 2017; Cignetti et al., 2010). Breeding programs with

55 the aim of incorporating wild resistance genes have initiated recently, but new genotypes are

56 not expected to be adopted in the short term (Bressano et al., 2019).

57 Survival fungi structures can remain viable for new infections up to four years (Cazón

58 et al., 2016a) which implies that a short peanut crop rotation is an inefficient disease

59 management technique in the current argentine production system. Local preliminary research

60 concerning chemical control of peanut smut reported a wide range of control efficacy higher

61 doses of DMI+QoI mixture fungicides presented the highest control efficacy better (Cazón et

62 al., 2013; Paredes et al., 2015a; Paredes et al., 2015b). In previous studies, we observed 58%

63 smut control with fungicides azoxystrobin+cyproconazole at doses of 1000 cm³/ha, which is

64 twice and half the recommended dose for peanut late leaf spot management caused by

65 *Passalora personata* (syn. *Cercosporidium personatum*) (Paredes et al., 2015b). In addition,

66 we compare the effect of time of the day on the fungicide smut control efficacy: fungicide

67 applications during the night had higher control efficacy than sprayings during the day

68 (Paredes et al., 2015c). This time of the application effect can be due to the fact that peanut

69 plants fold their leaves at night and open them in the daytime (a process known as nyctinasty),

70 allowing for more spraying drops to reach the soil surface.

71 No studies of fungicide sensitiveness of local *T. frezii* populations are registered in

72 Argentina, which is cornerstone knowledge for the setting of a chemical management strategy.

73 The lack of studies examining a wide set of fungicides to control peanut smut led us to perform

74 this work. The objectives of this work were to i) estimate the fungicides efficacy against *T.*

75 *frezii in vitro* conditions and ii) test the field performance of fungicides against peanut smut.

76

77 **2. Materials and Methods**

78 **2.1. In vitro sensitivity of fungicides based on mycelial growth test**

A mixture of 10 *Thecaphora frezii* isolates obtained from smutted pods in 2015 in General Deheza, (Córdoba province, Argentina) were used for the fungicide sensitivity test. Smut teliospores (100 mg) were suspended in aqueous solution of 0.63% NaOCl, agitated during 5 minutes, rinsed twice with sterile distilled water and resuspended in 2 ml sterile distilled water. Disinfected teliospores were placed in potato dextrose agar made up of broth extract of healthy grains at a rate of 50 g/l (Potato Peanut Dextrose Agar, PPDA). The plates were incubated at 25° C ± 1° in darkness (Astiz Gassó and Wojszko, 2011). After 7-10 days, the spores of *Thecaphora frezii* were germinated and colonies were transferred to a culture medium potato-dextrose agar 2% to obtain *T. frezii* pure colonies. The identities of all isolates were confirmed with specific primers for *T. frezii* (Cazón et al., 2016b).

To measure the *in vitro* sensitivity of fungicides, a mycelial growth test was carried out. Fungicide-amended agar medium for the characterization of fungal mycelial growth inhibition is one of the most common methods to determine fungicide sensitivity (Liang et al., 2015; Saville et al., 2015). Twelve fungicides products were used: four belong to the group of triazoles (DMIs) (difenoconazole, propiconazole, cyproconazole, tebuconazole), four to strobilurins (Q_oI) group (picoxystrobin, azoxystrobin, kresoxim-methyl, pyraclostrobin), one to carboxamide (SDHI) (penthiopyrad), one to dithiocarbamates (EBDC) (mancozeb), one to methyl benzimidazole carbamates (MBC) (thiophanate-methyl) and one to chloronitrile (chlorothalonil). Five concentrations of each active ingredient were analyzed: 100.00; 10.00; 1.00; 0.10; 0.01 µg a.i./ml medium. Petri plates without fungicides were used as experimental control. Each experimental unit was represented by a plate (55 mm diameter), with five repetitions per treatment.

Mycelial plug (6 mm in diameter) were extracted from actively growing *T. frezii* isolates 8-day-old culture. The plugs were transferred in the center of the Petri plates with PDA

amended with the concentrations of the fungicides of each treatment. Five replicate plates were

used for each fungicide concentration. Plates were incubated at 25 ºC in darkness conditions.

The radial growth (colony diameter) of each isolate was measured with a digital caliper in two perpendicular directions, and it was subtracted the original mycelial plug diameter (6 mm). The measurements were taken when the control plates mycelium reached the plate edge. The inhibition of mycelial growth relative to the treatment without fungicide was calculated and by logarithmic regression the concentration that inhibits 50% of mycelial growth (EC_{50}) was calculated.

The fungitoxicicity of fungicides was classified according Tonin *et al.*, (2015): EC50<1 µg/ml it is considered as highly fungitoxic; between 1 to 50 µg/ml as moderately fungitoxic; EC50 > 50 µg/ml as non-toxic.

2.2. Fungicides efficacy to control peanut smut trials

Two sets of replicated experiments were conducted during growing seasons 2014/2015 (from now on 2015) and 2015/2016 (from now on 2016). Peanut cultivar Granoleico, was used in all experiments due to the known susceptibility to smut (Oddino et al., 2013). Twelve fungicides labeled for peanut leaf spot were tested. A non-treated control was included in each experiment in which we sprayed water. We used two and a half fold the active ingredient dose recommended for peanut leaf spot control (Table 1). One set of trials was conducted in pots and the other one in field plots.

Table 1. Chemical group of fungicides active ingredients registered for the control of peanut leaf spot and rates used in this study by treatments for peanut smut control

Chemical group	Active ingredients	Rate g ai/ha
QoI	Picoxystrobin	120
QoI	Azoxystrobin	135

QoI	Kresoxim-Methyl	190
QoI	Pyraclostrobin	150
DMI	Difenoconazole	160
DMI	Propiconazole	200
DMI	Cyproconazole	75
DMI	Tebuconazole	300
SDHI	Penthiopyrad	120
EBDC	Mancozeb	1700
MBC	Thiophanate-Methyl	750
Chloronitriles	Chlorothalonil	1500

125

2.2.1. Field experiment

Field assays were conducted at AGD experimental station in General Deheza (province of Córdoba, Argentina - 32° 45′ 20.53″S, 63° 46′ 56.5″W), located in the main peanut producing region with high *T. frezii* inoculum field pressure (Paredes et al., 2017). The inoculum concentration in the experimental area was higher than 4500 smut teliospores/g of soil. Treatments were distributed upon a randomized complete block design with four replications. Plots consisted of four rows at 0.7-m spacing and 8 m long. Fungicides were applied at night (between 9 - 11 pm) considering the soil as spraying target, with a CO_2 pressurized backpack and handheld boom equipped with four nozzles (ALBUS ATR 80) delivering 120 L per ha approximately. The first application was done seven days after R2 stage (beginning peg) (Boote, 1982) and the second one 10 days after the first one.

137

2.2.2. Pots experiments

Two experiments with peanut plants growing in pots were conducted at INTA research facilities in Córdoba city (-31° 28' 3.8"S, -64° 8' 50.4"W). Single peanut plants were grown in

141   10 L pots containing a substrate composed of a 3:1 mixture of sterilized soil-vermiculite and *T.*

142   *frezii* teliospores. The inoculum was added at a rate of 10,000 teliospores/g of substrate by

143   drenching of a *T. frezii* spore suspension. Both, the *T. frezii* spores and the soil used to fill the

144   pots were obtained from the experimental area of the field trials. A completely randomized

145   design, with five (2014/15, from now on 2015) and eight (2015/16, from now on 2016)

146   repetitions was used for each treatment. Treatments consisted of two fungicide sprayings: at 7

147   to 10 days after R2 (beginning peg) and 10 days after the first one. Each fungicide application

148   consisted of three manual sprays (approximately 2.5 ml), directed to the plant base and pegs.

149

150   2.3. Disease assessment

151   Smut intensity assessment was performed at physiological mature crop stage (R8,

152   Boote, 1982) (Rago et al., 2017). Severity was visually estimated using a five-class scale

153   (Marinelli et al., 2008) which take into account both grains status within the pod (Figure 1).

154   Disease assessment in the field plots experiment was performed by collecting 1 m² from the

155   two central grooves of each plot (and all pods produced in that area were evaluated) and in the

156   pots experiment all the pods contained in the pots were evaluated.
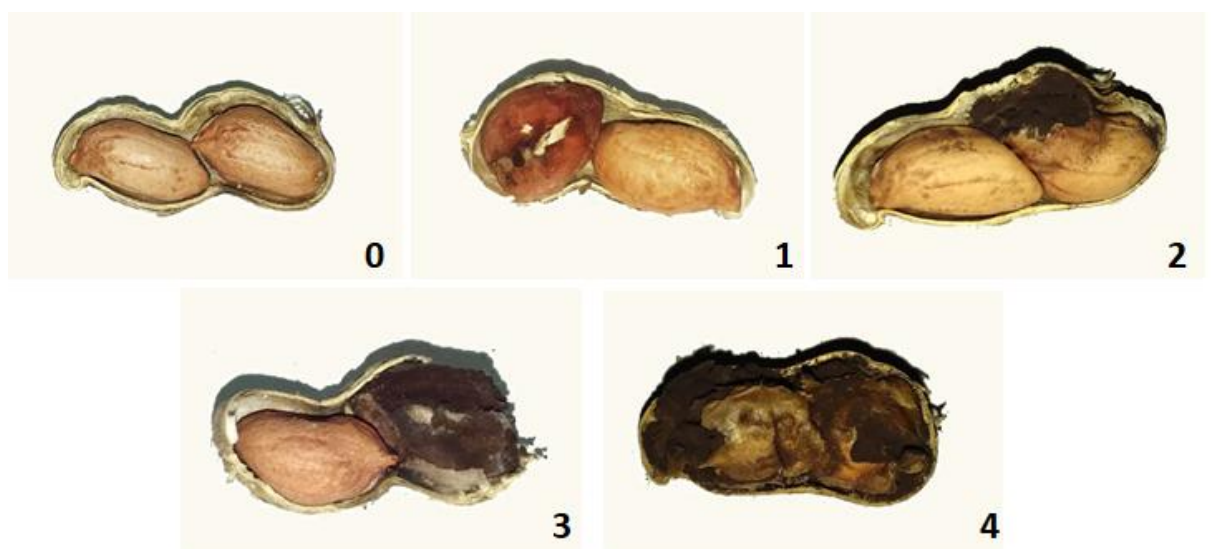

157

158   Figure 1. Severity five-class scale for peanut smut, where: 0 = both healthy kernels. 1 = presence of a

159   small sorus in single kernel. 2 = at least one kernel with half area affected. 3 = deformed pod, with one

160   single kernel completely smutted. 4 = deformed pod with two kernels completely smutted

161

162   For the purposes of this analysis, we used the proportion of severely damaged pods

163   (SDP, disease class 3 and 4) as the response variable. These disease classes are frequently lost

164   at harvest or discarded by the industry (Morichetti S. personal communication) and represent a

165   high impact in inoculum increase. SDP was calculated as:

166    $SDP = (n_3 + n_4) / N$ (1)

167   where n_3 and n_4 are the number of pods corresponding to disease severity class 3 and 4

168   respectively and N is the plot sample size.

169   Then, for graphical displaying of the results, smut control efficiency (CE) was

170   calculated by using the following formula:

171    $CE = (1 - (\text{Treatment SDP} / \text{untreated check SDP})) * 100)$ (2)

172

173   **2.4. Data statistical analysis**

174   Univariate generalized linear models (GLMs) were used to analyze SDP. Treatments

175   marginal means were estimated with the "emmeans" function from the emmeans R package

176   (Lenth 2018) and post-hoc comparisons among them were done with Tukey test at a

177   significance level of 5%.

178   Multivariate analysis was performed to integrate all the efficacy tests (Deepak et al.,

179   2006): principal component analysis (PCA) was conducted to the scaled variables, as: (x -

180   mean(x)) / sd(x), where x is each variable, and the scaling is done by dividing the (centered)

181   vectors of x by their standard deviations. CE% were obtained from the field plots and peanut

182   plants grown in pots trials (2015 and 2016). We obtained the correlation coefficients for each

183   variable with the first and second principal components to explain the variability explained by

184 the first and second principal component. Each fungicide (individuals, represented by points)

185 and their performance in each trial (variables, represented by vectors) are displayed together on

186 a biplot.

187 **3. Results**

188 **3.1. *In vitro* sensitivity**

189 *T. frezii* isolates grown 4.76 mm per day (± 0.14) in the not fungicide - amended control

190 plates. A wide range of sensibility to the evaluated fungicides was observed with the *T. frezii*

191 isolates: EC50 from 0.001 to >100. The highest mycelial growth inhibitions (lowest EC50

192 values) was observed with the DMI's fungicides, QoI's pyraclostrobin and azoxystrobin, and

193 penthiopyrad, EC50<0.1 (Figure 2). Moderately sensitive was registered with mancozeb (EC_{50}

194 = 6.28). The lowest sensitivity of *T. frezii* was observed with thiophanate-methyl (EC50 > 100

195 µg/ml). According to the EC_{50}, only thiophanate-methyl was classified as non-toxic, and

196 mancozeb as moderately fungitoxic, the rest of the a.i. were classified as highly fungitoxic.
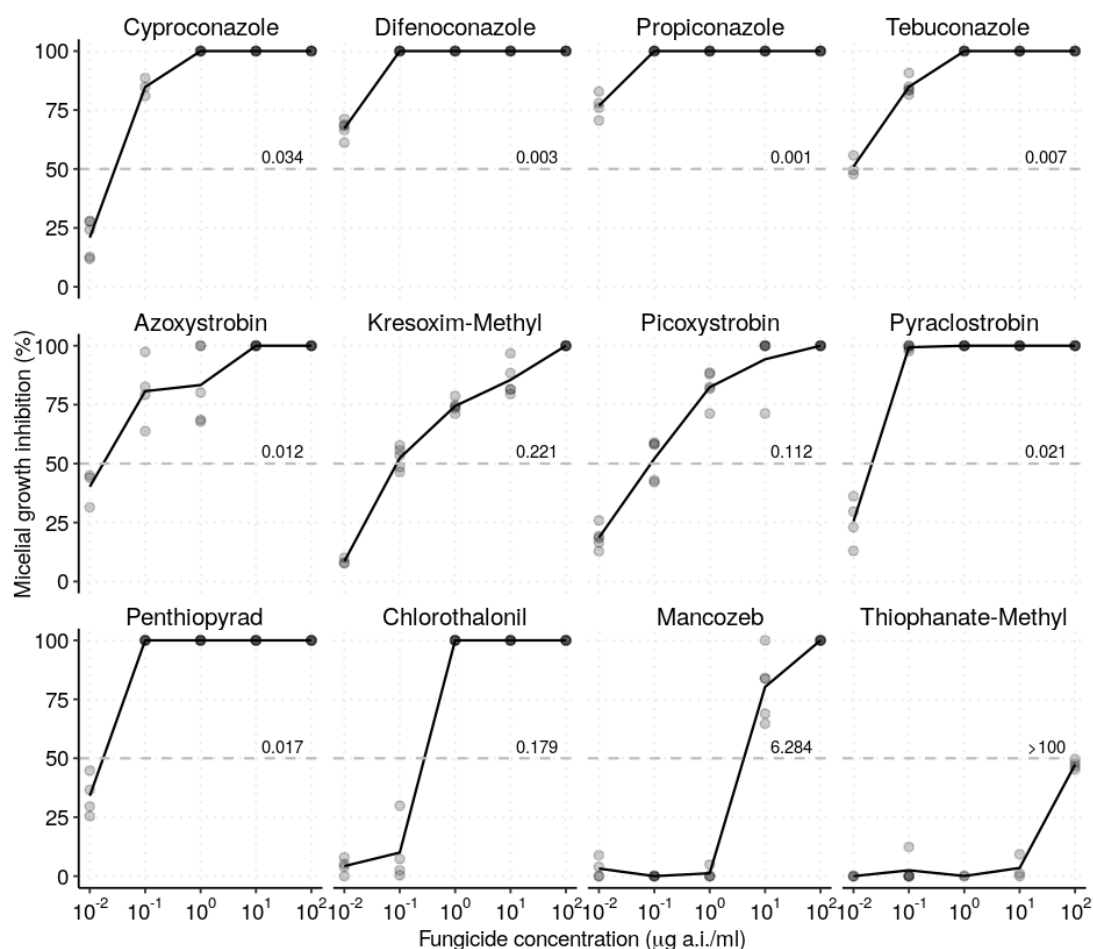
Figure 2. Mycelial growth inhibition curves according to fungicide concentration (μg a.i./ml) for active ingredients evaluated. Numbers on the central point-line corresponds at EC_{50}.

3.2. Control efficacy experiments

Accumulated precipitations and mean temperature registered in General Deheza during the peanut cropping season (December to April) in 2014/15, 2015/16 are presented in Table S1. A normal crop development (without severe hydric stress) was observed in both field experiments. A total precipitation of 465 and 417 mm was recorded during the pegging phenological stage (January to March) in 2015 and 2016 respectively.

Smut pressure in pots experiments, indicated by the mean SDP at the non-treated check plants, was higher in 2015 (0.73) than 2016 (0.52). Azoxystrobin presented the lowest SDP values in both years: 0.3 and 0.04 in 2015 and 2016, respectively. The latter values represented

59% and 92% control efficacy relative to their corresponding non-treated control. No significant differences in smut control were observed with difenoconazole (0.43 SDP, 41% control efficiency) in 2015 or from cyproconazole (0.09 SPD, 82% control efficiency) or tebuconazole (0.13 SPD, 74% control efficiency) in 2016. In an intermediate smut control efficacy group were observed tebuconazole, picoxystrobin and cyproconazole in 2015, and picoxystrobin, propiconazole, mancozeb, difenoconazole and kresoxim-methyl in 2016. On the other hand, the mean SDP for chlorothalonil, penthiopyrad, thiophanate-methyl and pyraclostrobin did not differ from the nontreated check in both years (Table 2; Figure 3).

Table 2. Severely damaged pods, control efficiency, and corresponding statistics for the effect of different active ingredients using for the control of peanut smut on pots experiment in 2015 and 2016.

	2015					**2016**			
Active ingredients	**SDPa**	**CLLb**	**CLUb**	**CEc**	**Active ingredients**	**SDP**	**CL$_L$**	**CL$_U$**	**CE**
Azoxystrobin	0.30	0.23	0.39	58.9	Azoxystrobin	0.04	0.02	0.09	92
Difenoconazole	0.43	0.36	0.51	41.1	Cyproconazole	0.09	0.06	0.14	82
Tebuconazole	0.51	0.44	0.58	30.1	Tebuconazole	0.13	0.08	0.19	74
Picoxystrobin	0.54	0.46	0.61	26	Picoxystrobin	0.19	0.14	0.25	62
Cyproconazole	0.56	0.48	0.63	23.3	Propiconazole	0.27	0.2	0.35	46
Kresoxim-Methyl	0.60	0.52	0.67	17.8	Mancozeb	0.28	0.21	0.36	44
Thiophanate-Methyl	0.65	0.57	0.72	11	Difenoconazole	0.29	0.22	0.36	42
Mancozeb	0.65	0.58	0.71	11	Kresoxim-Methyl	0.32	0.26	0.39	36
Pyraclostrobin	0.67	0.60	0.73	8.2	Pyraclostrobin	0.39	0.33	0.47	22
Propiconazole	0.71	0.63	0.78	2.7	Penthiopyrad	0.43	0.36	0.5	14
Penthiopyrad	0.72	0.63	0.79	1.4	Check	0.5	0.44	0.56	0
Check	0.73	0.65	0.80	0	Thiophanate-Methyl	0.51	0.43	0.58	0
Chlorothalonil	0.74	0.68	0.80	0	Chlorothalonil	0.52	0.45	0.59	0

[a] Proportion of severely damaged pods (disease classes: 3 - deformed pod, with one single kernel completely smutted and 4 - deformed pod with two kernels completely smutted).
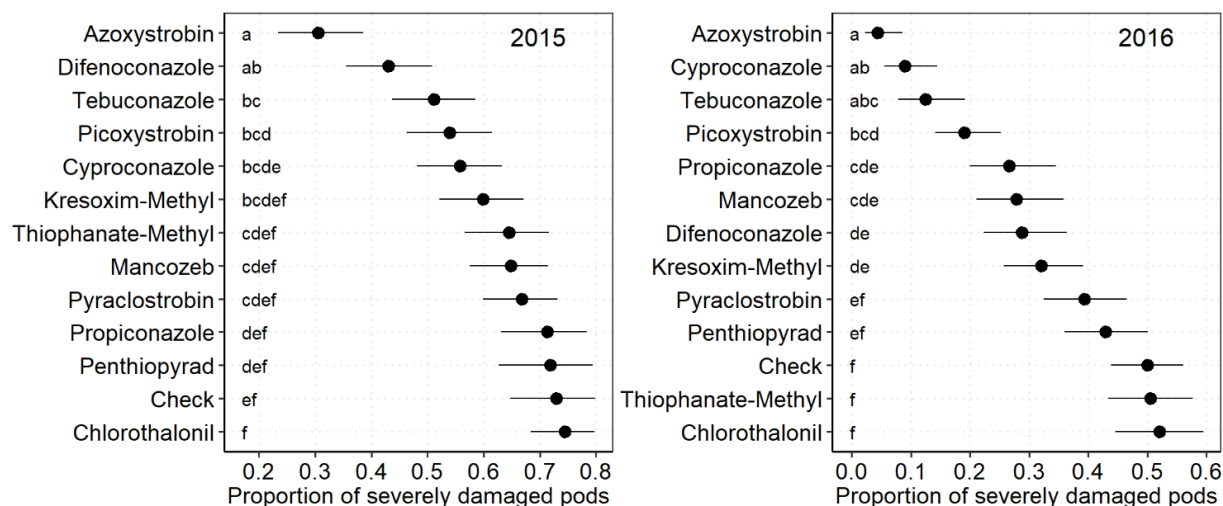
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226

227   Figure 3. Proportion of severely damaged pods for different active ingredients used for the control of

228   peanut smut on pots experiment in 2015 and 2016.

229
230   In the field experiments, mean SDP at the non-treated control was 0.39 (2015) and 0.43

231   (2016). Cyproconazole and azoxystrobin in 2015 presented the lowest SDP values: 0.21 and

232   0.25 (control efficacy of 47% and 37%, respectively) (P<0.05). Azoxystrobin was the most

233   efficient fungicide in 2016 to control smut, with a lowest SPD: 0.26. No significant differences

234   with the non-treated control in smut control was observed with kresoxim-methyl, thiophanate-

235   methyl, tebuconazole, penthiopyrad and chlorothalonil for both years (Table 3; Figure 4).

236

237   Table 3. Severely damaged pods, control efficiency, and corresponding statistics for the effect of

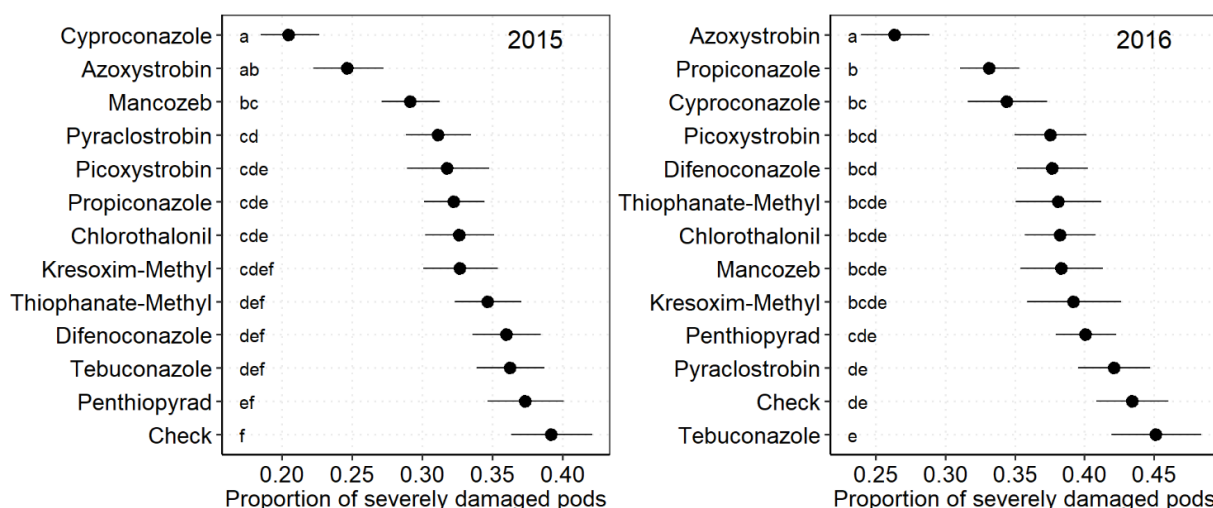238   different active ingredients using for the control of peanut smut on field experiments in harvest 2015

239   and 2016.

	2015					2016			
Active ingredients	SDP[a]	CL_L[b]	CL_U[b]	CE[c]	Active ingredients	SDP	CL_L	CL_U	CE
Cyproconazole	0.21	0.19	0.23	47.7	Azoxystrobin	0.26	0.24	0.29	39.5

Azoxystrobin	0.25	0.22	0.27	37.2	Propiconazole	0.33	0.31	0.35	23.7
Mancozeb	0.29	0.27	0.31	25.8	Cyproconazole	0.34	0.32	0.37	20.9
Pyraclostrobin	0.31	0.29	0.34	20.7	Picoxystrobin	0.38	0.35	0.40	13.8
Picoxystrobin	0.32	0.29	0.35	18.9	Difenoconazole	0.38	0.35	0.40	13.3
Propiconazole	0.32	0.30	0.34	17.9	Thiophanate-Methyl	0.38	0.35	0.41	12.4
Chlorothalonil	0.33	0.30	0.35	16.8	Chlorothalonil	0.38	0.36	0.41	12.2
Kresoxim-Methyl	0.33	0.30	0.35	16.6	Mancozeb	0.38	0.35	0.41	12.0
Thiophanate-Methyl	0.35	0.32	0.37	11.7	Kresoxim-Methyl	0.39	0.36	0.43	9.9
Difenoconazole	0.36	0.34	0.38	8.2	Penthiopyrad	0.40	0.38	0.42	7.8
Tebuconazole	0.36	0.34	0.39	7.4	Pyraclostrobin	0.42	0.40	0.45	3.2
Penthiopyrad	0.37	0.35	0.40	4.8	Check	0.44	0.41	0.46	-
Check	0.39	0.36	0.42	-	Tebuconazole	0.45	0.42	0.48	0

240   [a] Mean of the proportion of severely damaged pods (disease class 3 and 4)

241   [b] Lower (CL_L) and upper (CL_U) limits of 95% confidence interval around SDP

242   [c] Percentages of control efficiency of active ingredients calculated in relation to the untreated check

243   treatment.

244

245   Figure 4. Proportion of severely damaged pods for different active ingredients used for the control of

246   peanut smut on field experiments in 2015 and 2016.

247

248   **3.3. Multivariate analysis**

249   The multivariate analysis allowed us to integrate all the trials results: two independent

250   principal components (PC) accounted for 76.5% of the total variation (56.2% and 20.3% for

251   the PC1 and PC2 respectively). PC1 (horizontal axe) represented the control efficacy values in

252   the field plots trials (with correlation coefficients of 0.86 and 0.77, in 2015 and 2016

253   respectively) and pots experiments (with correlation coefficients of 0.83 and 0.73, in 2015 and

254   2016 respectively). The further right on the PC1-axis, the higher the efficacy control of the

255   fungicide. PC2 on the y-axis represented the EC50 values: the upper in the axis, the lower the

256   sensitivity of the smut to the fungicide. Considering this coordinate meaning, we may select as

257   best fungicides those ones located in the right quadrants, and the lower as possible:

258   azoxystrobin and picoxystrobin (QoI group) and cyproconazole and difenoconazole (DMI

259   group).

260   We observed that control efficacy in 2015 followed a similar trend in both type of

261   experiments (plant grown in pots and field plots), but a weak correlation among both

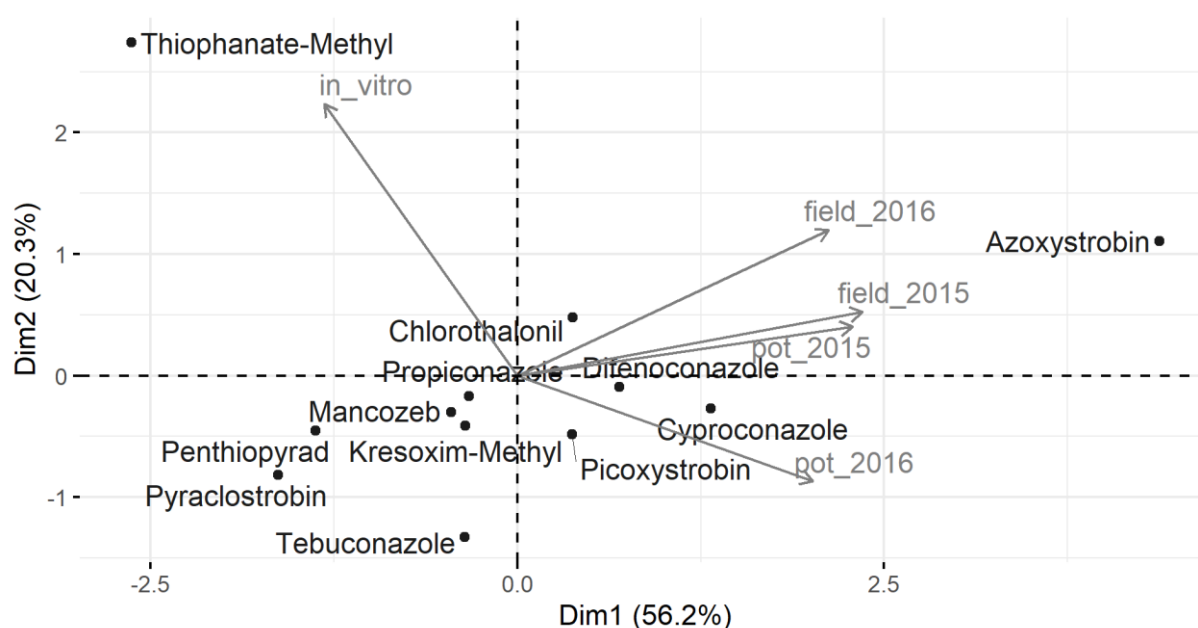262   experimental types was observed in 2016.

263

264 Figure 5. Biplot model showing relationship among fungicides (individuals, represented by
265 points) and their performance in each trial (variables, represented by vectors): in vitro
266 experiments and pot and field experiment in 2015 and 2016.

267

268 **4. Discussion**

269 Since its re-emergence in 2006, peanut smut continues increasing its prevalence and
270 incidence in the main Argentine peanut-growing region, without good perspectives for the
271 future due to the current absence of use of management practices for controlling smut (Rago et
272 al. 2017). By means of the present two-year fungicide-screening study we observed variability
273 in the available set of commercial fungicides, including highly efficacious active ingredients to
274 non-effective ones. To the best of our knowledge this is a first study exploring the chemical
275 management as a technique to maintain peanut smut in low intensity levels.

276 In vitro mycelial growth inhibition tests showed a general good performance of the
277 DMI´s group, QoI´s azoxystrobin and pyraclostrobin and SDHI´s penthiopyrad. The two last
278 chemical groups have as mode of action the inhibition of spore germination, process that was
279 not evaluated in the *in vitro* tests. This fact could have a potential sub-estimation effect of the
280 evaluated active ingredients since the smut spore germination is a fundamental first step on
281 epidemic triggering after the gynophore exudates stimulation (Astiz Gasso et al., 2008;
282 Marinelli et al., 2008). In relation to this both fungi cycle processes, Kosiada et al., (2011)
283 observed a weak correlation between mycelial growth and germination of teliospores and
284 basidiospores according to the sensitivity of some fungicides for head smut of corn
285 (*Sphacelotheca reiliana)*.

286 Another weak correlation was reported between results of laboratory and field
287 conditions experiments (Hollowell et al., 2003), which led us to perform pots and field trials

288   for assessing the fungicide efficacy to control peanut smut. In both years of the study we

289   observed that azoxystrobin was the fungicide with highest smut control efficacy levels.

290   Pavez Badilla et al. (2013), showed different levels of sensitivity *in vitro* for

291   pyraclostrobin and kresoxim-methyl (QoI) in front of the *Venturia inaequalis*, nevertheless

292   they assure that it is very difficult to extrapolate this type of investigation to the field

293   conditions due to the action mode. Differences in control levels for peanut smut were observed

294   compared to *in vitro* results. The DMIs a.i. showed EC_{50} lower than the rest of the chemical

295   groups. Cyproconazole has the highest EC_{50} comparatively with other DMIs, however it is one

296   of the a.i. that shows the highest control efficiency in field and pots experiments. For its part,

297   chlorothalonil and penthiopyrad (SDHI) have an EC_{50} like QoI, however did not demonstrate

298   disease control efficiency. Azoxystrobin, picoxystrobin, cyproconazole and tebuconazole were

299   the a.i. best responses demonstrated in the assessment; however, they are not the lowest EC_{50}

300   within the chemical groups to which they belong.

301   Individual performances of cyproconazole and azoxystrobin had the highest control

302   efficacy in the present study. However, higher performances were observed as mixture

303   formulations of the fungicides in previous field experiments under the same disease pressure

304   (4400 teliospores/g of soil): azoxystrobin + cyproconazole and azoxystrobin + picoxystrobin

305   reduced smut severity by 58 and 47% respectively relative to nontreated control (Paredes et al.,

306   2015b; Paredes et al., 2015d). This higher performance of the fungicides as mixtures could be

307   due to a "potentiation" effect (Cid, 2014).

308

309   **5. Conclusions**

310   There are multiple factors that affect the disease control. Therefore *in vitro* inhibition

311   effect of the active ingredients against *T. frezii* is not enough since there is not a direct

312   relationship between the EC_{50} and disease control. Active ingredients belonging to the same

313 chemical group do not predict the same peanut smut control. The effect can be more linked to

314 the intrinsic characteristics of the formulation or the active ingredient and not to the chemical

315 group. Azoxystrobin and cyproconazole were the active ingredients that showed best

316 responses, belonging to the QoI and DMI groups respectively. Results reported here allow us

317 to determine the effect of large number of the active principles registered for the peanut culture

318 in Argentina, being an important tool for the development of strategies for disease

319 management.

320

321 **Funding**

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437 **Supplementary tables**

438

439 Table S1: Data were extracted from AGD local station data: Rainfall (monthly precipitation), average

440 monthly maximum and minimum temperatures in the experimental peanut area during 2014/15;

441 2015/16.

442

	Rainfall (mm)		Temperature (°C)					
			Mean		Average max.		Average min.	
Month	2015/16	2016/17	2015	2016	2015	2016	2015	2016
December	38	122	22	24	32	31	14	16
January	89	123	24	23	32	30	18	18
February	255	249	21	24	28	30	16	18
March	121	45	21	19	28	26	16	13
April	57	143	20	15	28	21	13	11
Acumulated	560	682						

443

Highlights:

We observed variability in the smut control efficacy

there is not a direct relationship between the EC_{50} and disease control

Individual performances of cyproconazole and azoxystrobin had the highest control

The results can be considered for the integrative smut management strategy

Data in Brief