ARTICLE

Identification of sources of resistance to race 63-63 of *Pseudocercospora griseola* in common bean lines

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Abstract: *Angular leaf spot (ALS), caused by the fungus* Pseudocercospora griseola*, is one of the most important foliar fungal diseases in common bean (*Phaseolus vulgaris *L.). The search for new sources of resistance to ALS is a promising activity in common bean breeding programs. In this study, the reaction of 416 germplasm accessions from the Universidade Federal de Lavras (UFLA) to* P. griseola *(race 63-63, the most important and most aggressive race) was assessed under greenhouse conditions (plants in the V2 stage, fully developed unifoliolate leaves). We identified 102 (24.5%) resistant and 314 (75.5%) susceptible accessions. Among the resistant lines, more than half are Carioca grain type lines. This study characterizes the resistance of a wide collection of common bean genotypes. The identification of new accessions resistant to* P. griseola *is an important step in common bean breeding programs. These lines can continually be incorporated in backcrosses to obtain cultivars resistant to ALS.*

Keywords: *Phaseolus vulgaris L., Pseudocercospora griseola, artificial inoculation.*

INTRODUCTION

A common bean (*Phaseolus vulgaris* L.) cultivar should combine desirable genotypes for several traits to gain the acceptance of producers and consumers (Lima et al. 2015). Brazilian universities and other federal institutions have made efforts over the past 45 years to provide new cultivars of common bean with high grain yield, good plant architecture, resistance to the main pathogens, and a highly marketable grain type (Abreu et al. 2007, Melo et al. 2010, Pereira et al. 2012, Lemos et al. 2020). The germplasm collection of the Universidade Federal de Lavras (UFLA) is composed of several common bean lines developed by different breeding programs, genotypes collected from production areas, inbred lines, cultivars obtained from breeding programs mainly developed to increase yield, and lines from other countries (Lemos et al. 2020). However, many of these lines have not been improved for resistance to pathogens. Genetic resources support plant breeding and agricultural production and are thus essential to food security (Fowler and Hodgkin 2004). Efforts are required to use germplasm by identifying beneficial alleles for introgression in modern cultivars, particularly those controlling traits such as higher yield, resistance to

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biotic and abiotic stresses, and high nutritional qualities (Wang et al. 2017). Therefore, it would be useful to identify if the selection for other traits was also favorable to acquisition of disease resistance. Resistance to the main pathogens has been a challenge for breeders because they must continually incorporate new alleles for resistance to rapidly evolving pathogen populations (Nelson et al. 2018).

Angular leaf spot (ALS), caused by *Pseudocercospora griseola* (Sacc.) Crous and Braun, is one of the most devastating diseases in common bean, causing yield losses of up to 80% (Liebenberg and Pretorius 1997, Crous et al. 2006, Singh and Schwartz 2010, Nay et al. 2019). This disease mainly infects leaves and pods, inducing premature leaf drop and reduced grain quality (Borel et al. 2011). The use of resistant cultivars is one of the least expensive, safest, and most practical solutions for common bean producers. In crop plants, resistance is the foundation for disease management programs (Khan et al. 2020). However, the diversity of *P. griseola* and the emergence of new races of this pathogen are challenges for the development of cultivars with durable resistance (Silva et al. 2008, Abadio et al. 2012, Pereira et al. 2015, Pereira et al. 2019). An isolate of race 63-63 of *P. griseola* was chosen for use in this study because it is the most frequent race in Brazil (Pereira et al. 2019). This race is also more aggressive, breaking the resistance of the set of all different cultivars used for identification of *P. griseola* races (Silva et al. 2008, Nay et al. 2019). Therefore, this isolate may represent the variability of isolates that occurs in the field.

The incorporation of new sources of resistance to ALS should be a routine practice in breeding programs (Ddamulira et al. 2014, Pereira et al. 2019). However, there is little information about ALS resistance in the elite lines that are adapted to Brazilian environmental conditions. Furthermore, there are few reports of assessment of germplasm for ALS in the V2 stage under greenhouse conditions with artificial inoculation of the pathogen. Early evaluation of common bean plants (V2 stage, fully developed unifoliolate leaves) has been proposed to simultaneously evaluate numerous genotypes in germplasm banks (Pereira et al. 2011, Librelon et al. 2015, Pádua et al. 2016, Pereira et al. 2019b). The evaluation of a germplasm bank with improved cultivars is one of the first stages of a breeding program. The present study characterizes the ALS resistance of a wide collection of common bean genotypes.

MATERIAL AND METHODS

Plant material and fungal strain: A *Pseudocercospora griseola* strain (race 63-63) collected from the leaves and pods of a common bean crop in Patos de Minas, Minas Gerais, Brazil, was used in inoculations. A set of cultivars with differential resistance to ALS were used to classify the race (Nay et al. 2019). A total of 416 lines of different origins from the UFLA germplasm bank were used. These common bean lines were developed by breeding programs carried out over the past 45 years at the Universidade Federal de Lavras (UFLA) - Lavras, Minas Gerais, Brazil; other federal institutions, such as the Empresa Brasileira de Pesquisa Agropecuária (Embrapa); and other Brazilian universities. These common bean lines are classified morphologically into seven groups of commercial grain type: carioca, jalo, mulatinho, black, purple, red, and "other" types. The "other" type includes less frequent grain types, such as rosinha, speckled, yellow, grayish, green, and beige, classified as a single group.

Preparation of conidial suspension: mycelial discs of colonies of the *P. griseola* strain were placed in glass test tubes containing PDA (potato-dextrose-agar) medium and kept at 24 °C in a BOD (Biological Oxygen Demand) incubator for seven to ten days, with a photoperiod of 12 h. After that period, an inoculum suspension was prepared by adding 8 mL sterile distilled water to the tubes and scraping the surface with a brush to release conidia. The conidial suspension was then filtered through a layer of Miracloth (Chicopee Mills, Inc., New York, NY, USA), and the concentration was quantified in a Neubauer counting chamber. Sterile distilled water was added to the final suspension to reach the concentration of 2×10^4 conidia mL^{-1}.

Phenotyping in the greenhouse: To assess ALS severity, an experiment was conducted with two replications and nine plants per plot in a greenhouse with temperature of 25 °C and humidity of 85%. Common bean lines were sown in 162-cell polystyrene trays containing Plantmax® commercial subtract. The line MAIII-16.159 was used as a resistant control and Rosinha as a susceptible control to assess ALS severity. Eight days after sowing seedlings (V2 stage, fully developed unifoliolate leaves) were inoculated by spraying both sides of the leaf surface with the conidial suspension at the concentration of 2×10^4 conidia mL^{-1}. Fifteen days after inoculation, disease severity was assessed by the 1 to 9 scoring scale proposed by Librelon et al. (2015): 1 = absence of symptoms; 2 = 0.1 to 0.5% of area with symptoms; 3 =

0.6 to 4.0 % of area with symptoms; 4 = 4.1 to 7.0% of area with symptoms; 5 = 7.1 to 16% of area with symptoms; 6 = 16.1 to 26% of area with symptoms; 7 = 26.1 to 32% of area with symptoms; 8 = 32.1 to 38% of area with symptoms; and 9 = 38.1 to 60% of area with symptoms. After that, average scores were calculated, and the common bean lines were classified as resistant (1 to 3) or susceptible (3.1 to 9).

RESULTS AND DISCUSSION

Assessment of the accessions revealed different levels of resistance to the 63-63 race (Table 1, 2, and 3). In general, of the 416 lines assessed in the present study, 102 (24.5%) were resistant and 314 (75.5%) were susceptible (Figure 2). Evaluation of the proportion of resistant and susceptible lines in each group showed that half of the Jalo lines were resistant, followed by purple (41.4%), red (40%), black (26.2%), carioca (22.2%), other (19.4%), and mulatinho (14.3%). About 60% of the lines assessed are of the carioca grain type (Figure 1). Carioca (cream-colored seed coat with brown streaks) is a common bean genotype obtained from many crosses and has wide genetic variability (Perseguini et al.

Table 1. Reaction to angular leaf spot (ALS) and scores for ALS severity of 164 common bean accessions (not carioca grain) and the susceptible control from the UFLA germplasm bank assessed in a greenhouse

Accession*	Reaction and ALS score**		Accession*	Reaction and ALS score**		Accession*	Reaction and ALS score**		Accession*	Reaction and ALS score**	
Cornell [B]	R	1	CNF 243 [J]	R	3	MulatinhoVR [M]	S	3.9	UTF 996 [B]	S	4.9
ERIPARSA 1 [Y]	R	1.6	Jalo-6 [J]	R	3	BAT 304 [W]	S	3.9	ESAL 532 [M]	S	4.9
ESAL 521 [Bg]	R	1.6	CNF 252 [R]	R	3	UTF 982002 [B]	S	4	FT 120 [B]	S	5
IAPAR 20 [B]	R	1.6	Jaime 155 [Y]	R	3	Irai [Bd]	S	4	CapixabaPrec. [Ro]	S	5
ESAL 543 [P]	R	1.7	Jalo-8 [J]	S	3.1	Vermelhinho [R]	S	4	LM 30333 [Ro]	S	5
ESAL 503 [P]	R	2	Jaime 185 [Y]	S	3.1	Rojo Seda [R]	S	4.1	Feijão Favinha [M]	S	5.1
Negrito [B]	R	2.1	Mãezinha [Ro]	S	3.1	Maria da Fé [Ro]	S	4.1	CIAT 354 [W]	S	5.1
LP-808 [B]	R	2.1	Porrillo 70 [B]	S	3.1	ESAL 506 [Bw]	S	4.1	ESAL 549 [B]	S	5.2
Costa Rica 1031 [B]	R	2.1	CNF 05 [P]	S	3.1	Purple 90 [P]	S	4.1	IPA 1 [P]	S	5.2
ESAL 562 [M]	R	2.2	LM 30330 [Bg]	S	3.2	Jalo-1 (Pintado) [Bd]	S	4.1	ESAL 536 [Y]	S	5.2
CNFP 7726 [B]	R	2.2	ESAL 621 [Gy]	S	3.2	Jalo-7 [J]	S	4.1	ESAL 539 [W]	S	5.4
ESAL 574 [P]	R	2.2	ARC-4-Cultivado [B]	S	3.2	A-140 [Bw]	S	4.2	IAPAR 16 [Bg]	S	5.5
CIX-16.9 [J]	R	2.2	CIAT 539 [P]	S	3.2	VP-21 [B]	S	4.2	CNFP 9328 [B]	S	5.5
Bagajo [Bg]	R	2.2	Jaime 122 [P]	S	3.2	Jaime 194 [P]	S	4.2	DOR 157 [B]	S	5.8
Rio Tibagi [B]	R	2.3	POT 51 [B]	S	3.3	Desconhecido [Y]	S	4.2	LM 30406 [Bg]	S	5.8
ESAL 608 [P]	R	2.4	Jaime 199 [Bg]	S	3.3	Negro Argel [B]	S	4.2	Safira [P]	S	5.9
CNF 255 [Y]	R	2.4	ESAL 518 [M]	S	3.3	CNFP 10802 [B]	S	4.2	Paraná 67 [Bg]	S	6
ESAL 523 [Bg]	R	2.4	Pintado [Bd]	S	3.4	Baetão [B]	S	4.3	Diacol Andino [Bd]	S	6.1
Paraná [Bg]	R	2.4	ESAL 525 [Bg]	S	3.4	A-354 [M]	S	4.3	ESAL 540 [P]	S	6.3
CNF 246 [Bg]	R	2.4	Jalo-3 (Pintado) [Bd]	S	3.4	CIAT A-296 [Bg]	S	4.3	CIAT 311 [Ro]	S	7
ESAL 537 [Bg]	R	2.5	Jalo-9 [J]	S	3.4	ESAL 595 [Bd]	S	4.3	Milionário [B]	S	7.1
ESAL 550 [J]	R	2.5	CIAT 250 [B]	S	3.4	ESAL 686(P-24) [Bw]	S	4.3	Flor de Mayo [Bg]	S	7.3
ESAL 533 [M]	R	2.5	Small White [P]	S	3.5	ESAL 597 [M]	S	4.3	CIAT 249 [B]	S	7.3
Bolinha [Y]	R	2.5	IAPAR 31 [Bg]	S	3.5	CNF 10 [P]	S	4.3	ESAL 510 [W]	S	7.3
BRS Valente [P]	R	2.5	FT Nobre [B]	S	3.5	Cai Folha [M]	S	4.3	LM 30630 [B]	S	8
VP-23 [B]	R	2.5	CNFP 9346 [B]	S	3.5	CIAT 245 [B]	S	4.3	Roxinho 31 [R]	S	8.1
ESAL 652 [P]	R	2.6	ESAL 526 [P]	S	3.5	AN 730340 [P]	S	4.3	ESAL 546 [P]	S	8.2
Hulk [G]	R	2.7	Jalo-4 [J]	S	3.6	Rosinha G-2 [Ro***]	S	4.4	LINEA 29 [M]	S	8.2
Jaime 182 [P]	R	2.7	Jalo-2 (Pintado) [Bd]	S	3.6	ESAL 1 [Bg]	S	4.4	ESAL 568 [J]	S	8.3
Jalo [J]	R	2.7	Amarelinho [Y]	S	3.6	Jaime 173 [Bg]	S	4.4	P-105 Patos [Bg]	S	8.4
Jaime 196 [P]	R	2.7	IAPAR 14 [B]	S	3.7	Jamapa [B]	S	4.5	ESAL 639 [P]	S	8.4
ICA PIJAO [B]	R	2.8	ERIPARSA [Y]	S	3.7	VP-16 [B]	S	4.5	ESAL 563 [P]	S	8.5
ESAL 502 [P]	R	2.8	Porrillo Sintético [B]	S	3.8	Ponciano [B]	S	4.6	Moruna Rosa [P]	S	8.6
ESAL 660 [P]	R	2.8	IPA-8 [M]	S	3.8	TB 9701 [B]	S	4.8	CIAT 57 [P]	S	8.6
CNFP 7966 [B]	R	2.9	Fortuna 1895 [Bg]	S	3.8	CIAT A-254 [Gy]	S	4.8	BAT 41 [Ro]	S	8.6
ESAL 664 [P]	R	2.9	Jaime 224 [Bg]	S	3.8	Perry Marrow [M]	S	4.8	ESAL 572 [Bg]	S	8.6
ESAL 606 [P]	R	2.9	ESAL 524 [Bg]	S	3.8	ESAL 542 [M]	S	4.8	Paraná 1 [B]	S	8.9
Jalo EEP [J]	R	2.9	FEB 163 [P]	S	3.8	BRS Radiante [Bd]	S	4.8	ESAL 589 [Bg]	S	9
Vermelho G-2 [R]	R	2.9	Jalo-5 [J]	S	3.8	ESAL 610 [Bw]	S	4.8	Franguinho [B]	S	9
VP-20 [B]	R	3	Jaime 192 [Bg]	S	3.9	CNFP 10798 [B]	S	4.9	ESAL 618 [B]	S	9
ESAL 595/GOL [Bd]	R	3	Jaime 158 [Y]	S	3.9	TB 9707 [B]	S	4.9	ESAL 583 [M]	S	9

* B: black, Y: yellow, Bg: beige, P: purple, J: jalo, M: mulatinho, G: green, R: red, Gy: gray, Bd: brindle, Ro: rosinha, W: white, and Bw: brown grain type. ** R = resistant, S = susceptible; based on the diagrammatic scale (1-9) proposed by Librelon et al. (2015). *** Susceptible control

2011). It represents most beans consumed in Brazil (Del Peloso and Melo 2005) and, consequently, is most used in breeding programs (Lemos et al. 2020).

Other studies on the characterization of common bean lines aiming at ALS resistance were carried out in Brazil (Oliveira et al. 2004, Reis-Prado 2006, Sartorato 2006, Costa et al. 2010, Moda-Cirino et al. 2012, Pádua et al. 2016, Almeida et al. 2020). In these studies, overall, 14% of accessions were resistant to *P. griseola*. A study conducted at the Universidade Federal de Viçosa assessed common bean accessions under field and greenhouse conditions and found three accessions (MAI-18-13, VC 16, and Vermelhão) that were resistant under both greenhouse and field conditions and therefore suitable as sources of resistance in breeding programs (Moda-Cirino et al. 2012).

In the present study, lines from the recurrent selection program for ALS resistance conducted by UFLA and the Empresa Brasileira de Pesquisa Agropecuária (Embrapa) were evaluated. Many studies have evidenced the success obtained in

Table 2. ALS severity scores of 57 resistant common bean accessions and the resistant control with carioca grain type from the UFLA germplasm bank assessed in a greenhouse

Accession	ALS Score *	Accession	ALS Score *	Accession	ALS Score*
LR 9115332	1.4	CI-257-1	2.4	Aroana	2.8
MAII-14	1.5	ESAL 657	2.5	P5-9	2.9
MAII-10	1.5	ESAL 501	2.5	AN 910522	2.9
MAIII-16.159**	1.5	H-4-18	2.5	H-4-12	2.9
A-285	1.6	ESAL 640	2.6	Carioca IAC	2.9
MAIV-18-264	1.6	PF 9029984	2.6	A-767	2.9
ESAL 632	2	ANPAT 8.12	2.6	R-29	3
ESAL 612	2	MAV-1-7	2.6	CIII-H-4-12	3
UTF 0037	2	MAV-3-36	2.6	LP 806	2.1
BP-28	2	ESAL 651	2.6	ESAL 553	2.2
LR 9115315	2.0	OPNS/VC3-177	2.6	ESAL 590	2.4
LR 9115302	2.1	MAVI-21	2.7	ESAL 613	2.5
CV-55	2.2	BP-24	2.7	ESAL 635	2.7
CVII-45.5	2.2	MAVI-39	2.7	ESAL 620	2.9
ESAL 630	2.3	ESAL 516	2.7	ESAL 609	1.3
ESAL 648	2.3	CNFC 10764	2.7	ESAL 505	2.2
ESAL 631	2.3	ESAL 683	2.8	Carioca TU	1.9
CI-107-6	2.4	LP 98-31	2.8	TU x Carioca	2.3
LR 720982 CP	2.4	MAII-16	2.8	TO	2.8

* based on the diagrammatic scale proposed by Librelon et al. (2015).
** Resistant control.

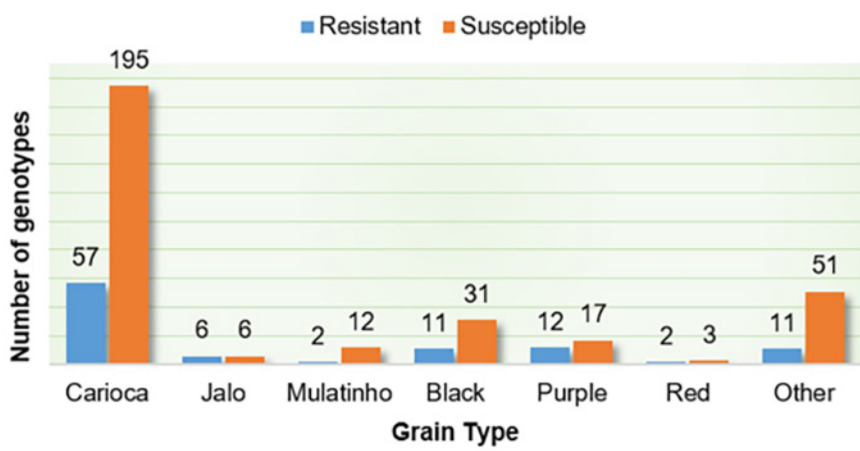

Figure 1. Grain type classification of 416 common bean lines, and number of lines resistant and susceptible to the 63-63 race of *Pseudocercospora griseola* in each grain type group assessed in a greenhouse.

integrating resistance in this recurrent selection program (Amaro et al. 2007, Arantes et al. 2010, Rezende et al. 2014, Pereira et al. 2015, Lemos et al. 2020, Librelon et al. 2020). The recurrent selection program for ALS carried out at UFLA started in 1998 from crossing seven carioca type bean cultivars with ten sources of resistance to angular leaf spot (Amaro et al. 2007). This program is in its nineteenth selection cycle, and many lines have been obtained in each cycle (Lemos et al. 2020). Pereira et al. (2019b) assessed 144 common bean lines in the final stage of the breeding program and lines from ten cycles of this recurrent selection program for resistance to ALS; they confirmed that common bean lines derived from different cycles exhibited a good level of resistance to *P. griseola*. In the present study, eight lines (MAII-14, MAII-10, MAIV-18-264, MAV-1-7, MAV-3-36, MAVI-21, MAVI-39, and MAII-16) from this recurrent selection

Table 3. ALS severity scores of 195 susceptible common bean accessions with carioca grain type from the UFLA germplasm bank assessed in a greenhouse

Accession	ALS Score*	Accession	ALS Score*	Accession	ALS Score *	Accession	ALS Score*
MAII-2	3.1	CVII-85.1	3.9	ESAL 509	4.4	H-4-15	5.8
LP 98-76	3.1	OPNS/VC3-41	3.9	BRSMG Pioneiro	4.4	ESAL 643	5.9
Michelite	3.1	AN 910523	4	OPNS/HRES-85	4.5	H-4-13	5.9
MAII-3	3.1	D-205	4	CII-337	4.5	H-4-20	6
ESAL 653	3.1	FT-84-292	4	MAII-8	4.5	ESAL 547	6.5
UTF 0018	3.1	H-4-24	4	CVII-85.17	4.5	OPNS/VC3-148	6.5
CVII-39.18	3.2	CI-140	4	CNFC 9468	4.6	BP-30	7.2
CVIII-119-4	3.2	CI-164-3	4	OPNS/VC3-119	4.6	FP-5.13	7.4
CIX-11.4	3.3	UTF 0019	4	CNFC 8014	4.6	CIAT 437	7.6
R-27	3.3	CIV-432	4	CIX-12.6	4.6	ESAL 535	7.7
IAPAR 81	3.3	CIV-82	4	OPNS/HRES-17	4.7	P45(TOx E.501)	7.9
CIV-151	3.3	OP-S-82	4	ESAL 582	4.7	P-180	8
CIII-R-3-19	3.3	CNFC 8055	4	BRS Majestoso	4.7	ESAL 512	8.3
ESAL 569	3.4	VC-6	4	D-186	4.7	ESAL 642	8.3
D-245	3.4	MAIV-18.265	4	CVIII-39-24	4.7	ESAL 527	8.3
CI-164-2	3.4	OPNS/VC3-198	4	P-70	4.7	ESAL 564	8.5
CNFC 8010	3.4	ESAL 616	4.1	CNFC 8006	4.7	ESAL 513	8.7
Opns/VC3-175	3.4	H-4-17	4.1	T-16	4.8	Rio Negro	8.8
MAII-22	3.4	CNFC 8011	4.1	BP-31	4.8	ESAL 522	8.9
AN 910546	3.4	IAPAR 57	4.1	Aporé	4.8	ESAL 615	8.9
Carioca 80	3.5	ESAL 654	4.1	CI-107	4.8	ESAL 566	8.9
Carioca 300 V	3.5	ESAL 658	4.1	ESAL 655	4.8	ESAL 617	8.9
ANPAT 5.12	3.5	H-4-7	4.1	D-26	4.8	RP-2	9
OP-S-156	3.5	UTF 0029	4.1	CNFC 8007	4.9	ESAL 507	9
R-3	3.6	ESAL 538	4.1	BRS Pérola	4.9	A 488	3.3
CNFC 8005	3.6	R-8	4.1	RELAV 37.19	4.9	H-87	3.7
UTF 0013	3.6	CNFC 9498	4.1	H-4-10	4.9	ESAL 619	3.9
CIII-H-4-3	3.6	H-4-16	4.2	LH-9	4.9	ESAL 591	3.9
CIV-449	3.6	H-4-5	4.2	CIV-588	5	Jaime 184	4
CI-107-2	3.6	OPNS/HRES-30	4.2	OP-S-154	5	ESAL 520	4.3
BP-34	3.6	ESAL 649	4.2	ESAL 531	5.1	Jaime 208	4.4
CVII-39.24	3.6	ESAL 600	4.2	ESAL 599	5.1	ESAL 514	4.7
ESAL 598	3.6	ESAL 634	4.2	ESAL589	5.1	ESAL 517	5
MAII-5	3.6	R-18	4.2	CI-48	5.1	Feijão Chileno	5.2
CIV-498	3.7	CI-107-3	4.2	PUAD III	5.1	R-17	5.5
CNFC 8156	3.7	CI-164-4	4.2	H-4-6	5.2	CIAT 240	6.6
ESAL 646	3.7	OP-S-64	4.2	CII-281	5.2	ESAL 565	7.6
H-4-22	3.7	CNFC 8008	4.2	OP-S-30	5.3	CVII-119.4	8.6
CIV-143	3.7	CI-164	4.3	P-106	5.3	DOR 95	8.9
ESAL 584	3.7	ESAL 656	4.3	T-71	5.3	ESAL 579	8.9
CI-257-2	3.8	R-34	4.3	ESAL 515	5.3	ESAL 511	9
OPNS/HRES-45	3.8	CNFC 9474	4.3	CIX-16.9	5.4	ESAL 644	3.5
A-242	3.8	CII-348	4.3	OPNS/VC3-170	5.4	Batatinha	3.7
R-1	3.8	CNFC 9435	4.3	D-282	5.4	CVII-85.11	4
CNFC 8009	3.8	ESAL 601	4.3	ESAL 623	5.4	CNF 266	4.9
UTF 0004	3.8	B-1	4.4	CII-175	5.6	ESAL 588	8.1
CIV-135	3.8	ESAL 592	4.4	BRSMG Talismã	5.7	P76(TOxE.501)	3.1
CI-107-5	3.9	H-4-11	4.4	CNFC 9444	5.8	ESAL 586	8.9
ESAL 611	3.9	FP 3.47	4.4	CVII-55-3	5.8		

* based on the diagrammatic scale proposed by Librelon et al. (2015).

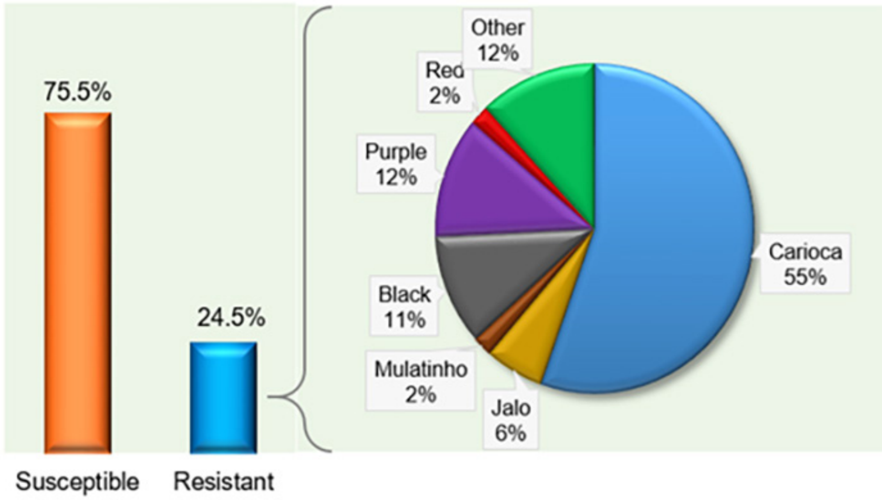

Figure 2. Percentage of resistant and susceptible common bean lines, and percentage of each grain type in the lines resistant to the 63-63 race of *Pseudocercospora griseola* assessed in greenhouse.

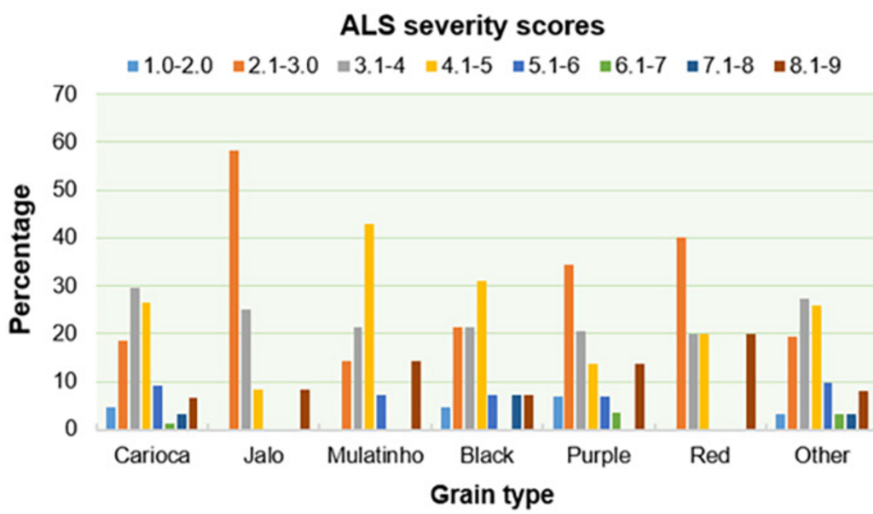

Figure 3. Distribution of ALS severity scores from the 63-63 race of *Pseudocercospora griseola* for common bean lines in relation to grain type assessed in a greenhouse.

program were resistant to race 63-63 of *P. griseola*. This confirms the prevalence of race 63-63 in the field, because the evaluation of ALS resistance on progenies in each cycle is carried out under field condition, with a natural inoculum.

From the UFLA breeding program for grain yield and other favorable characteristics, 19 lines were considered resistant. The results indicate that the breeding program has been effective in achieving its goals, and they also show that it is possible to obtain or maintain resistance, even when selecting for other characteristics, such as grain yield.

The search for new sources of resistance to *P. griseola* should be a constant activity, mainly because of its high genetic variability (Mahuku et al. 2002, Sartorato 2004, Pereira et al. 2015). It is difficult to obtain durable resistance, due to the extensive diversity of *P. griseola* and its ability to produce new virulent strains (Nay et al. 2019). Therefore, resistant cultivars become susceptible over time, due to constant co-evolution between pathogen and host (Nelson et al. 2018). The extensive virulence diversity of *P. griseola* suggests that common bean cultivars with single genes for

ALS resistance will likely succumb to new virulent races of *P. griseola* in the future (Nay et al. 2019). The 63-63 race for being the most aggressive, well represents the variability present in the field. This justifies the use of race 63-63 of *P. griseola* for purposes of assessment. Plant breeders always need to return to germplasm banks to obtain new sources of resistance. Therefore, lines that have already been improved for several other traits of economic interest, such as those in the UFLA germplasm bank, can be incorporated into other breeding programs for disease resistance.

The histograms of the scores according to the common bean grain type group showed a tendency of normal distribution for the following groups: carioca, mulatinho, black, purple, and "other" (Figure 3). This is due to the quantitative inheritance of ALS resistance (Amaro et al. 2007, Nay et al. 2019), known as quantitative disease resistance (QDR). This type of resistance has intermediate phenotypes that are controlled by multiple genes of small effect (Nelson et al. 2018). The relationship between phenotypes and molecular mechanisms for quantitative resistance is not as well understood as it is for qualitative resistance (Nelson et al. 2018). This becomes a challenge for breeders and reinforces the importance of the search for new sources of resistance to ALS.

Identification of genotypes for resistance to ALS in germplasm collections have been carried out in different locations in the world (Pastor-Corrales et al. 1998, Rodríguez et al. 2019, Rezene and Mekonin 2019, Ddamulira 2019). These studies increase the importance of characterizing accessions in germplasm banks in breeding programs to be able to exchange information and genetic material. These data are relevant during pre-breeding, as it is necessary to characterize a large number of accessions for several traits aiming to establish a breeding program and avoid narrowing the genetic base (Singh et al. 2019). According to Perseguini et al. (2011), the success of a breeding program to increase genetic diversity depends on the choice of divergent parents for the hybridizations.

As the *P. griseola* 63-63 race represents the field scenario, this study presents important and valuable data regarding the resistance of common bean lines to ALS. This study provides scientific and practical knowledge, because information regarding the ALS resistance of accessions from an important germplasm bank is made available for characterization of ALS resistance in the common bean line accessions. This will allow selection and recommendation of lines in breeding programs for resistance to ALS.

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