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Soybean seed origin effects on physiological and sanitary quality and crop yield

Procedência de sementes de soja e efeitos sobre a qualidade fisiológica, sanitária e produtividade da cultura

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Abstract

The suitable establishment of a crop depends on seed quality, among another factors. However, with high production costs many producers use uncertified seeds, to reduce expenses with this input at sowing time. The objective was to evaluate germination, vigor and health of soybean seeds, diseases incidence in cvs. NS 5445 IPRO and BMX Ativa RR, whose seeds were of certified and uncertified origins, as well as yield components and grain yield of soybeans, with or without fungicides application. The experiments were conducted in the 2015/16 and 2016/17 crop season, in Erechim-RS. Two experiments were carried out in a completely randomized design (DIC): one in the laboratory, under a 2 x 2 factorial scheme (cultivar x origin); and another in the field in a homogeneous area, in a 2 x 2 factorial scheme (with/without fungicide application and certified/uncertified seed) for two cultivars, both with four replications. The variables evaluated were: germination and seed health, yield (kg ha^{-1}), thousand grains weight (g), number of grains per plant, and incidence of foliar fungal diseases. The main fungi identified in seeds were *Aspergillus* sp., *Penicillium* sp. and *Fusarium* sp. The highest incidence percentage were obtained in uncertifed seeds, at two harvests. Both cultivars and origins presented the minimum germination required for commercialization, however, certified seeds had better performance for seed vigor. As for normal seedlings, there was a significant difference only for the 2016/17 crop season, with the highest percentage obtained in certified seeds (52.0% for NS 5445 and 73.5% for BMX Ativa). Best productivity was achieved with cultivation of certified seeds associated with fungicides in both crops and cultivars. For thousand grains weight (TGW) there was no difference in origin, but only for cultivar and fungicides apply. The number of grains per plant was higher in plants from certified seeds and that received fungicides, being cv. BMX Ativa the most responsive for the two harvests analyzed. The main diseases found in the two harvests were: Asian rust, powdery mildew, mildew, septoriosis and cercosporiosis. However, seed origin, in both crops, did not differ in the incidence of Asian rust, powdery mildew and mildew, but for septoriosis and cercosporiosis, considered soybean late season diseases, seed origin is a determining fator.

Key words: *Glycine max* (L.) Merrill. Pathogens. Seed quality. Yield.

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Resumo

O adequado estabelecimento de uma lavoura depende da qualidade das sementes utilizadas. Contudo, os custos de produção fazem com que muitos produtores façam uso de sementes salvas, para reduzir gastos com esse insumo no momento da semeadura. Objetivou-se avaliar a germinação, vigor e a sanidade de sementes de soja, a incidência de doenças nas cvs. NS 5445 IPRO e BMX Ativa RR, cujas sementes eram de procedências salva e certificada, assim como os componentes de rendimento e a produtividade de grãos de soja, após a aplicação ou não de fungicidas na cultura. Os experimentos foram conduzidos nas safras 2015/16 e 2016/17, no município de Erechim (RS). Dois experimentos foram conduzidos em delineamento inteiramente casualizado (DIC): um em laboratório, em esquema fatorial 2 x 2 (cultivar x origem); e outro no campo, em área homogênea, em esquema fatorial 2 x 2 (com/sem aplicação de fungicida e semente certificada/não certificada) para duas cultivares, ambas com quatro repetições. As variáveis avaliadas foram: germinação e sanidade de sementes, produtividade média (kg ha^{-1}), peso de mil grãos (g), número de grãos por planta, e incidência de doenças fúngicas foliares. Os principais fungos identificados nas sementes foram *Aspergillus* sp., *Penicillium* sp. e *Fusarium* sp., sendo os maiores percentuais de incidência obtidos em sementes salvas, nas duas safras. Ambas as cultivares e procedências apresentaram a germinação mínima exigida para comercialização, porém, as sementes certificadas destacaram-se quanto ao vigor. Quanto às plântulas normais, houve diferença significativa apenas para a safra 2016/17, sendo os maiores percentuais obtidos em sementes de procedência certificada (52,0% para NS 5445 e 73,5% para BMX Ativa). A melhor produtividade foi alcançada com o cultivo de sementes certificadas associadas ao uso de fungicidas em ambas as safras e cultivares. No componente de rendimento peso de mil grãos (PMG) não houve diferença quanto à procedência, mas apenas para cultivar e aplicação de fungicidas. O número de grãos por planta foi maior em plantas provenientes de sementes certificadas e que receberam aplicação de fungicidas, sendo a cv. BMX Ativa a mais responsiva para as duas safras analisadas. As principais doenças encontradas nas duas safras foram: ferrugem asiática, oídio, míldio, septoriose e cercosporiose. Entretanto, a procedência das sementes, em ambas as safras, não provocou diferença quanto à incidência de ferrugem asiática, oídio e míldio, porém, para septoriose e cercosporiose, consideradas doenças de final de ciclo da soja, a procedência da semente é um fator determinante.

Palavras-chave: *Glycine max* (L.) Merrill. Patógenos. Qualidade de sementes. Rendimento.

Introduction

The use of high vigor seeds at the time of sowing may provide increases of between 20% and 35% in grain yield, since these seeds ensure adequate crop establishment and faster closure between rows (KOLCHINSKI et al., 2005; FRANÇA NETO et al., 2010). In this sense, the use of certified seeds produced within the required norms contributes to increased productivity (SCHEEREN et al., 2010).

However, utilization rate of certified soybean seed is still low in Brazil, with increasing use of seeds saved from the crop for sowing for the next crop (MENTEN et al., 2010). In most cases, seed processing is not conducted properly, with the intention of reducing costs, and this may compromise crop establishment. It is estimated that about 20 to 25% of the soybean market in Brazil, which covers 30 million hectares, is produced from saved seeds and "pirates"; this directly affects the breeder and multiplier companies (PEIXOTO, 2017).

In addition, some pathogens that cause diseases in soybean shoots, such as late crop season diseases, are transmitted by seeds and their occurrence may vary from crop to crop or from region to region, with severity dependent on meteorological conditions, cultivar susceptibility and pathogen presence (ITO, 2013).

Seed health plays important role in the successful cultivation and yield exploitation of a crop species. Among the various factors that affect seed health, the most important are seed-borne fungi that, not only lower seed germination, but also reduce seed vigor resulting in low yield (ABDULSALAAM; SHENGE, 2011). Therefore, the lack of knowledge of seed sanitary quality used may have a detrimental effect on crop establishment.

Subsequent to the establishment of the crop, it is still susceptible to diseases that affect the aerial part, among them, highlight the Asian rust of the soybean caused by the fungus *Phakopsora pachyrhizi* Sydow & Sydow, capable of causing 30 to 75% losses in crops. The use of fungicides is still the main form of control of soybean Asian rust (KLOSOWSKI et al., 2016). The integration of chemical control methods and seed certification may contribute to greater crop sanitary quality.

The objective of this study, therefore, was to evaluate seed germination, vigor and sanitary quality, as well as soybean disease incidence, using cvs. NS 5445 IPRO and BMX Ativa RR, with certified and uncertified seeds. In addition, yield and yield components of plants from these seeds were investigated, with and without fungicide application, in the 2015/16 and 2016/17 crop seasons.

Material and Methods

The experiments were conducted in Erechim, RS (27 ° 37’50 “S, 52 ° 14’11” W, altitude: 753 m) during the 2015/16 and 2016/17 seasons. The climate is Cfa type (temperate humid with hot summer) according to classification system established by Köeppen, with rainfall distributed throughout the year (CEMETRS, 2012). The soil is a Red Latosol Aluminoferric humic - Oxisol (STRECK et al., 2008). Soil samples were collected at depth of up to 0.10 m and the following chemical properties determined: pH 5.4; organic matter (OM) 3.6%; P 5.7 mg dm^{-3}; K 89 $cmol_c$ dm^{-3}; Al 0.2 $cmol_c$ dm^{-3}; Ca 5.6 $cmol_c$ dm^{-3}; Mg 2.8 $cmol_c$ dm^{-3}; and Cation Exchange Capacity (CEC) 14.2 $cmol_c$ dm^{-3}.

The soybean cultivars investigated were NS 5445 IPRO and BMX Ativa, (maturity class: 5.4 and 5.6 respectively) both with certified and uncertified seed origin. Before field sowing, the following laboratory tests were performed:

Sanitary test: performed according to methodology adapted from the Manual for Sanitary Seed Analysis (BRASIL, 2009a), with eight replicates of 25 seeds for each cultivar (certified and uncertified seeds), distributed in “gerbox” boxes using the blotter test method without freezing. Seeds were incubated at 25 ± 2 °C with a 12-h photoperiod for seven days and examined using a stereoscopic and optical microscope. The percentage (%) of seeds affected by each fungal genus, on the number of total seeds, was determined for each treatment, according to published methods (BRASIL, 2009b; HENNING, 2015).

Germination test: eight replicates of 25 seeds of each cultivar (certified and uncertified seeds) were distributed on sterilized germitest paper, moistened with distilled, sterilized water, at the proportion of 2.5 times the dry paper weight. Then, rolls containing seeds were prepared and placed in a germination chamber at 25 ± 2 ºC with a 12-h photoperiod; evaluations were performed at five and eight days after sowing. The first evaluation involved counting of all germinated seeds that gave rise to normal seedlings. In the second count involved counting the seedlings, classified as normal and abnormal, and non-germinated seeds (hard and dead) for both cultivars (BRASIL, 2009a).

The field experiment was conducted in an area where black oats and black oat + forage turnip had covered during the 2015/16 and 2016/17 winters, respectively. With both crops, the cover was desiccated using glyphosate herbicide 30 days before soybean sowing; this was performed on November 26, 2015 and November 15, 2016, respectively. The spacing between rows was 0.5 m, with seed deposition along the sowing line being performed manually. A seed drill was used only for opening the groove and depositing the fertilizer. Seed density was 18 seeds per linear meter, with the aim of obtaining a final stand of 320,000 plants ha^{-1} for both cultivars.

The experimental design was completely randomized (DIC) and the homogeneous area was used, in a 2 × 2 factorial scheme (with/without fungicide application and certified/uncertified seed) for two cultivars, with the following treatments: T1) NS 5445 certified with application of fungicide; T2) NS 5445 certified without application of fungicide; T3) NS 5445 uncertified with fungicide application; T4) NS 5445 uncertified without application of fungicide; T5) BMX Ativa certified with fungicide application; T6) BMX Ativa certified without application of fungicide; T7) BMX Ativa uncertified with fungicide application; T8) BMX Ativa uncertified without application of fungicide. For each treatment there were four replications, totaling 32 experimental units. Each plot was 4 m long by 3 m wide, totaling 12 m².

Seed treatment for both cultivars was carried out with pyraclostrobin + methyl thiophanate + fipronil at the dose of 200 mL of the commercial product for 100 kg of seeds, plus 100 mL ha^{-1} of cobalt + molybdenum. On the day of sowing, seeds were inoculated with 100 g of peat-based inoculant containing *Bradyrhizobium elkanii* (SEMIA 5019) and *Bradyrhizobium japonicum* (SEMIA 5079) for each 50 kg of seeds.

For basic fertilization, NPK mineral fertilizer with formula 02-23-23 was used at an application rate of 300 kg ha^{-1}. In post-emergence of soybean, weed control was performed throughout the field, using two applications of glyphosate at a rate of 3 L ha^{-1} in the initial stages V2 (second node). At V6 stage (sixth node), weeds that were not controlled by herbicide application were manually removed in order to avoid competition with the crop.

Four applications of fungicide were carried out during crop development for T1, T3, T5 and T7 treatments. Two applications of fungicide trifloxystrobin (strobilurins) + prothioconazole (triazole) (400 mL ha^{-1} + 150 mL ha^{-1} of adjuvant) were used at the V6 and R1 stages and two applications of azoxystrobin (strobilurins) + benzovindiflupir (carboxamide) fungicide (200 g ha^{-1} + 600 mL of adjuvant) were used at stages R5.1 and R6. Fungicide was applied using a sprayer equipped with pressurized CO_2 with a TXA 8002 VK tapered nozzle and a constant pressure of 29.0 Psi, resulting in a constant flow of 150 L ha^{-1}. Those plots for T2, T4, T6 and T8 treatments did not receive fungicide application, otherwise all other treatments were the same.

In all experimental plots, insecticides containing the following active ingredients were applied: lambda-cyhalothrin + chlorantraniliprole (75 mL ha^{-1}); bifenthrin (160 mL ha^{-1}); flubendiamide (70 mL ha^{-1}); thiamethoxam + lambda-cyhalothrin (200 mL ha^{-1}); and imidacloprid + bifenthrin (400 mL ha^{-1}). Insecticides were used as the presence of insect pests was observed, according to the levels of economic damage established for the crop, considering: for caterpillars (soybean caterpillar and looper caterpillar) - 20 caterpillars greater than 1.5 cm or 30% defoliation in the vegetative phase or 15% defoliation in the reproductive phase; pods caterpillar (*Spodoptera* spp.): 10 caterpillars per meter or 10% of pods attacked; and bedbugs (brown, green, small green and green belly): 2 bedbugs per meter (grain crop) (GRIGOLLI, 2016; SALVADORI et al., 2016). The application was carried out using the same equipment used for application of fungicides.

Ten leaf samples (trifolia) were collected from the middle third of each of the 32 experimental units before each application of fungicide: 42, 63, 81 and 95 days after sowing (DAS) in 2015/16; 40, 58, 74 and 92 DAS in 2016/17. The leaf samples were then evaluated in the laboratory for the presence of disease. Diagnosis of any disease present was made with the aid of a stereoscopic and optical microscope and by consulting specialized literature on soybean diseases (HENNING et al., 2014).

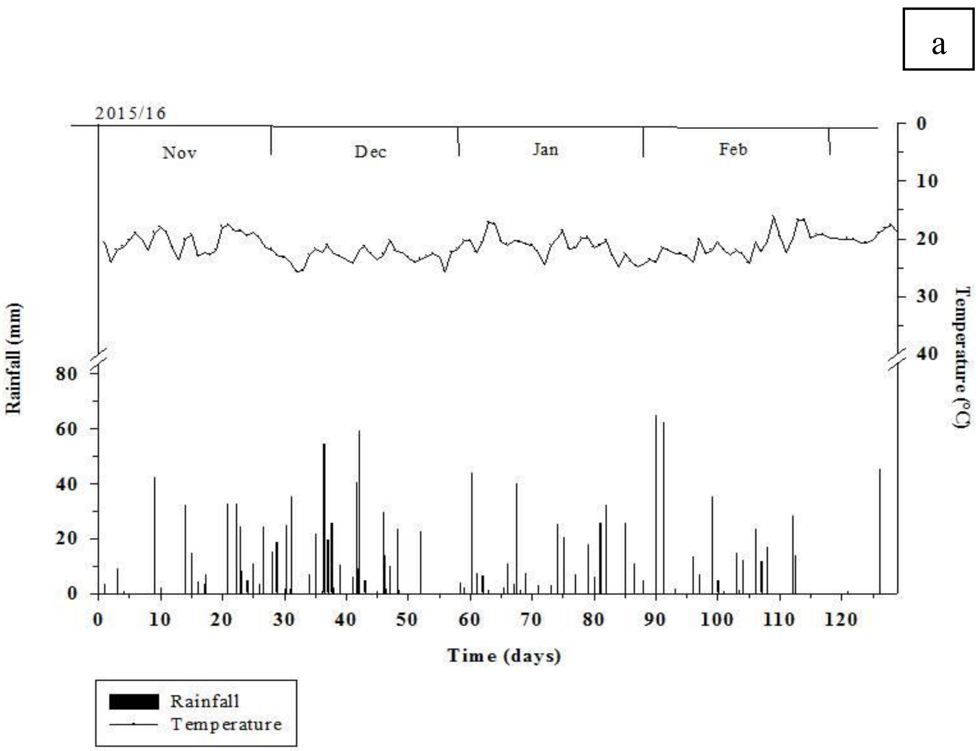
The plots were harvested, involving a useful area of 4.0 m², when all the plants were at the harvesting maturity stage (R8-R9 stage) (EMBRAPA, 1996).

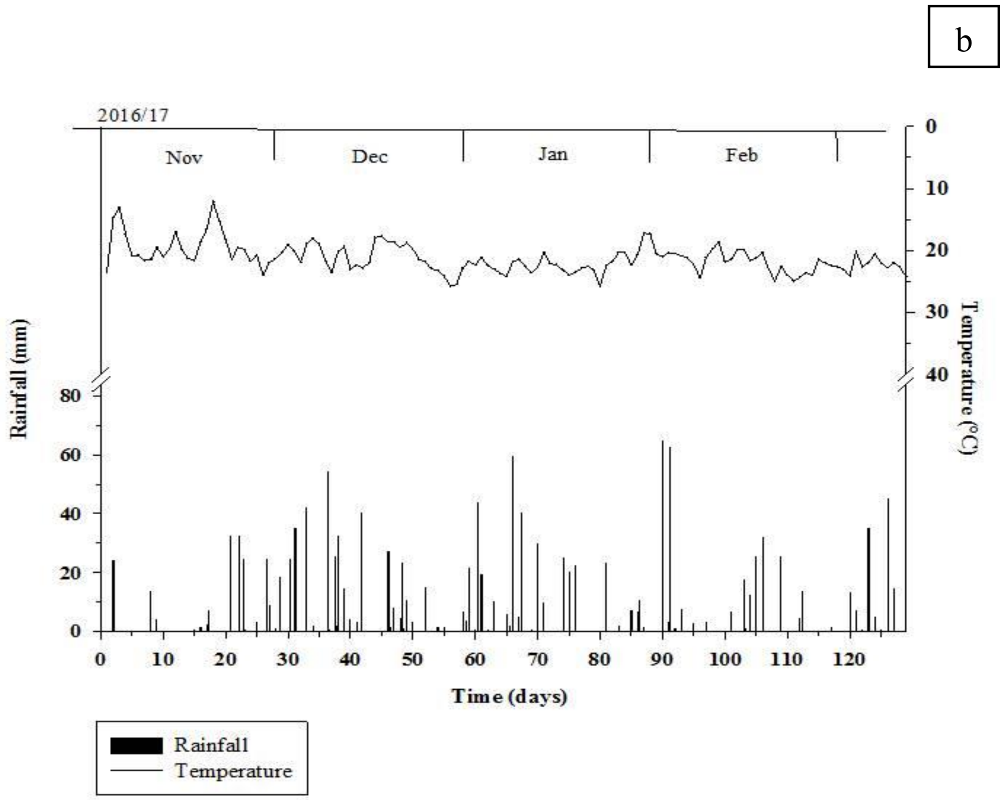
The samples were tracked with a Plot Combine and, afterwards, evaluations of productivity were carried out (kg ha^{-1}). The number of grains per plant was determined from a representative sample of six plants harvested at random in the useful area of each plot. The thousand grains weight for each sample was then added to the total grain weight of each treatment to determine productivity (kg ha^{-1}).

Before computing the thousand grains weight (TGW), a 50 g sample of soybean grain from each plot was submitted to moisture determination at 105 °C for 24 hours (BRASIL, 2009a). Subsequently, each sample was weighed for moisture determination, which was then corrected to 13%. To determine the thousand grains weight, eight replicates of 100 grains each were weighed and the mass calculated (BRASIL, 2009a).

The data of rainfall (mm) and average temperature (°C) during the experiment, for both harvests investigated, are shown on Figure 1; the data were obtained from the automatic surface observation meteorological station located in Erechim-RS and linked to the National Institute of Meteorology (INMET). Data obtained from the experiment were submitted to analysis of variance ($p \leq 0.05$) and, when the F test was significant, the means were compared using the Tukey test ($p \leq 0.05$). All analyses were performed using the statistical software ASSISTAT version 7.7 (SILVA; AZEVEDO, 2009).

Figure 1. Averages of temperature (°C) and precipitation (mm) between november (sowing) and february (harvest) for 2015/16 (a) e 2016/17 (b) crop season, Erechim-RS.





Source: INMET (2015/16; 2016/17).

Results and Discussion

In the 2015/16 crop was observed for cv. NS 5445, with uncertified seeds, germination reduction in relation to NS 5445 certified, and BMX Ativa, certified and uncertified, which expressed higher percentages (Table 1). For the 2016/17 crop season, certified seeds of cvs. NS 5445 and BMX Ativa reached 96.5% germination, while uncertified seeds from cvs. NS 5445 and BMX Ativa obtained lower germination percentages, with 89.0% and 91.5%, respectively. For the cultivars there was no statistical difference between the two seasons (Table 1).

Table 1. Averages of germination (G), normal seedlings (NS) and *Aspergillus* sp. (ASP), *Penicillium* sp. (PEN) and *Fusarium* sp. (FUS) incidence, cvs. NS 5445 IPRO e BMX Ativa, of uncertified and certified seeds, evaluated before and after the field trial, for 2015/16 and 2016/17 crop season.

Cultivar	Origin	2015/16				
		G	NS	ASP	PEN	FUS
		%				
NS 5445 IPRO	Certified	100.0 aA[1]	72.0 aA	51.7 aB	63.0 aB	5.4 aB
	Uncertified	94.0 aB	68.5 aA	78.0 aA	79.5 aA	9.8 aA
BMX Ativa	Certified	99.0 aA	78.0 aA	25.0 bB	69.0 aB	2.2 bB
	Uncertified	96.5 aA	72.0 aA	43.5 bA	83.0 aA	4.5 bA
C.V. (%)		2.6	5.7	6.6	9.5	19.8

continue

continuation

				2016/17		
NS 5445 IPRO	Certified	96.5 aA	52.0 aA	53.0 aB	61.0 bB	7.4 aB
	Uncertified	89.0 aB	44.0 bB	77.5 aA	75.0 aA	10.5 aA
BMX Ativa	Certified	96.5 aA	73.5 aA	19.0 bB	66.5 aB	6.2 aB
	Uncertified	91.5 aB	24.5 bB	51.0 bA	77.5 aA	10.7 aA
C.V. (%)		2.4	10.2	13.5	6.4	16.9

[1] Averages follow by the same lower case letter in column do not differ for cultivar and by capital letter, in column, for seed origin, by test F ($p \leq 0.05$).

Regardless of the seed origin (certified/uncertified) and cultivar, it was evident that the soybean seeds investigated were within the minimum limit of 80% germination required by legislation for commercialization and sowing (BRASIL, 2009a; BRASIL, 2013).

Normal seedling percentages for the first count germination (Table 1) did not differ in the 2015/16 season. However, in the 2016/17 season, certified seeds showed greater vigor in relation to uncertified seeds: 52.0% for NS 5445 and 73.5% for BMX Ativa. In the same season, with seeds of certified origin, cultivar BMX Ativa showeded greater vigor (73.5%) than NS 5445 (52.0%). However, when evaluating the performance of cultivars from uncertified seeds, NS 5445 superiority was observed over BMX Ativa.

Rampim et al. (2016) also observed that certified seeds produced a higher germination percentage and, consequently, greater vigor in the first count germination test. Moreover, in the same study, uncertified seeds produced 11.5% as normal seedlings, whereas with certified seeds this value reached 89.5%, a difference of 78%.

In seed sanitary test, *Aspergillus* sp., *Penicillium* sp. and *Fusarium* sp. were found in both evaluated cultivars and with both certified and uncertified seed origins (Table 1). For the 2015/16 season, there was a presence of *Aspergillus* sp. (78.0% and 43.5%), *Penicillium* sp. (79.5% and 83.0%) and *Fusarium* sp. (9.8% and 4.5%) in cultivars NS 5445 and BMX Ativa, respectively, both of uncertified origin. The same was observed in the 2016/17 season, in which the incidence of *Aspergillus* sp. (77.5% and 51.0%), *Penicillium* sp. (75.0% and 77.5%) and *Fusarium* sp. (10.5% and 10.7%) was higher for uncertified seeds of cultivars NS 5445 and BMX Ativa, respectively, than with certified seeds (Table 1).

In this sense, the presence of these storage and field fungi in seeds of sourced origin, associated with possible damage to seed physical and physiological integrity during harvesting, drying and/or storage, can affect seed germination and vigor (COCHRAN, 2006). Similar to results observed in this study, Bellé et al. (2016) demonstrated the incidence of *Penicillium* sp. in uncertified soybean seeds, produced in the Northern state of Rio Grande do Sul. They inferred that the high incidence of pathogens associated with soybean seeds may be related to the use of the same area, year after year, for this crop, increasing the potential for infection by fungi inoculum, probably introduced by contaminated seeds which act as vehicles for the dissemination of pathogens.

Seed sanitary quality is related to genetic factors and edaphoclimatic conditions during the crop season, which may benefit or hinder pathogen development. Thus, the final expression of sanitary quality and, consequently, physiological quality is linked to the conditions under which the culture is exposed in the field and during storage (ALBRECHT et al., 2008; RAMPIM et al., 2016).

Regarding the application or not of fungicides for the control of soybean diseases in the 2015/16 and 2016/17 seasons (Table 2), a higher impact was observed on productivity of cv. BMX Ativa for both origins in 2015/16 without fungicide application, causing a reduction of 57.8% with certified seed (1694.2 kg ha^{-1}) to 53.5% with uncertified seed (1686.2 kg ha^{-1}), compared to the same cultivar and origin with fungicide application (4016.5 kg ha^{-1} and 3630.7 kg ha^{-1}, respectively). In this harvest, a smaller impact was observed on the productivity of cv. NS 5445 with both sources of seed, with a yield reduction of 34% for NS 5445 uncertified (2169.9 kg ha^{-1}) and 35.6% for certified NS 5445 (2509.3 kg ha^{-1}) without application of fungicides (Table 2).

Table 2. Grain yield (kg ha^{-1}), thousand grain weight (g) and grain number per plant of soybean, cvs. NS 5445 IPRO e BMX Ativa, of uncertified and certified seeds, evaluated in 2015/16 and 2016/17 crop season.

Cultivar	Origin	2015/16		2016/17	
		Fungicide		Fungicide	
		With	Without	With	Without
		Grain Yield (kg ha^{-1})			
NS 5445 IPRO	Certified	3894.3 aA[1]	2509.3 aB	4103.0 aA	3582.5 aA
	Uncertified	3285.8 bA	2169.9 abB	3987.2 aA	3447.2 aA
BMX Ativa	Certified	4016.5 aA	1694.2 bB	4247.8 aA	3300.8 aB
	Uncertified	3630.7 abA	1686.2 bB	3704.0 aA	3254.6 aA
C.V. (%)		10.8		17.0	
		Thousand grain weight (g)			
NS 5445 IPRO	Certified	196.9 aA	162.3 aB	177.8 aA	157.1 aB
	Uncertified	199.3 aA	173.8 aB	183.4 aA	168.0 aB
BMX Ativa	Certified	167.9 bA	127.1 bB	179.6 aA	152.2 aB
	Uncertified	179.4 bA	120.8 bB	177.2 aA	154.6 aB
C.V. (%)		6.0		5.2	
		Number of grains per plant			
NS 5445 IPRO	Certified	107.7 bA	72.5 aB	120.4 bcA	111.4 bcA
	Uncertified	94.4 cA	63.0 bB	107.1 cA	98.5 cA
BMX Ativa	Certified	129.7 aA	56.4 bB	177.1 aA	139.4 aB
	Uncertified	114.6 bA	60.5 bB	135.1 bA	122.3 bB
C.V. (%)		5.5		6.4	

[1] The averages followed by the same lower case letter in the column do not differ to cultivar and by capital letter in the row for fungicide application by the Tukey test ($p \leq 0.05$).

In the 2016/17 season crop, there was no statistically significant difference in productivity for cv. NS 5445 with seed of both origins (certified and uncertified), and with or without application of fungicides (Table 2). The cv. BMX Ativa, whose seeds were certified, showed a reduction of 22.3% (3300.8 kg ha^{-1}) in productivity compared to the same plots that received fungicide treatment (4247.8 kg ha^{-1}).

Comparing the productivity of cv. NS 5445 certified and uncertified for 2015/16, a decrease of 15.6% to 13.5%, respectively, was verified in the plots with certified seeds (from 3894.3 kg ha^{-1} to 3285.8 kg ha^{-1}) in relation to uncertified seeds (from 2509.3 kg ha^{-1} to 2169.9 kg ha^{-1}). In the 2016/17, there was no significant difference in the variables tested. These observations corroborate the results of Barros et al. (2008) who evaluated three applications of pyraclostrobin + epoxiconazole, found increases of 32.8% and 25.1% in soybean yield.

The lower impact caused by diseases on productivity in 2016/17 can be attributed to a winter with temperatures (Figure 1) below the normal average, which is 14.5 °C (CEMETRS) for Erechim-RS region. As a consequence, there was a reduction in the population of alternative host plants of *Phakopsora pachyrhizi*, which implied a reduction in the initial inoculum of the pathogen (GODOY et al., 2016). In the 2015/16 season crop, it was shown that in the treatment without fungicide there was a reduction in the thousand grains weight: 34.6 g in NS 5445 of certified origin; 25.5 g for NS 5445 uncertified; 40.8 g for BMX Ativa of certified origin; and 58.6 g for BMX Ativa of uncertified origin. Also in this season, a greater thousand grains weight was obtained in the cv. NS 5445 of certified origin (196.9 g) and uncertified (199.3 g), did not differ statistically regarding the origins (Table 2).

In the following harvest (2016/17), for treatments with fungicide application, an increase in thousand grains weight was registered in NS 5445 certified (20.7 g) and uncertified (15.4 g); and BMX Ativa certified (27.4 g) and uncertified (22.6 g), in relation to treatments without application of fungicides (Table 2). A larger thousand grains weight for soybean was also observed by Barros et al. (2008) in treatments with one or more applications of pyraclostrobin + epoxiconazole and by Doreto et al. (2012) with application of azoxystrobin + cyproconazole. Additionally, Toloti et al. (2016), pointed out the existence of an inverse relationship between the severity of Asian soybean rust and grain weight.

Another important yield component in the 2015/16 crop, influenced by the treatments used, was the number of grains per plant. For cv. BMX Ativa, with seeds of certified origin and with fungicide application, the value obtained was much higher than in plots without fungicide, with a difference of 73.3 grains per plant. Under the same conditions, cv. BMX Ativa with seeds of uncertified origin presented 114.6 grains per plant, that is, 15.1 grains less than with certified seeds. For cv. NS 5445 with fungicide application, there was a similar response and the highest number of grains was obtained in plots using seeds of certified origin (107.7 grains per plant) in relation to uncertified seeds (94.4 grains per plant) (Table 2).

Also, with regard to the number of grains per plant in 2016/17, similar results were observed in which, regardless of fungicide application, cv. BMX Ativa with seeds of certified origin produced the highest number of grains per plant (177.1 and 139.4 grains with and without the application of fungicides, respectively) (Table 2). In 2015/16, cvs. BMX Ativa and NS 5445 with certified and uncertified seeds, respectively, presented a lower number of grains per plant without application of fungicides. Under this condition, in 2016/17, a lower number of grains per plant was observed in cv. NS 5445, for origins. Late season diseases are directly implicated in early crop defoliation, reducing the photosynthetic capacity. As a consequence, the diseases shorten the crop cycle and impair the filling of the grains, which results in a lower grain weight (GODOY; CANTERI, 2004).

Figure 1 shows the temperature (°C) and precipitation (mm) conditions for the 2015/16 season crop (Figure 1a) and for 2016/17 (Figure 1b), during which the experiment was conducted. In the evaluation of disease incidence, Asian rust (*Phakopsora pachyrhizi*), septoriosis (*Septoria glycines*) and cercosporiosis (*Cercospora kikuchii*) occurred late in 2016/17, in relation to the previous period (Tables 3 and 4). This may be mainly associated with the low average temperature and lower precipitation at the beginning of the cycle, which would have directly interfered with the optimal conditions for the establishment of a stable parasitic relationship (SARTO et al., 2013; DALLA LANA et al., 2015).

As the same weather conditions, powdery mildew (*Microsphaera diffusa* Cooke & Peck) was most most evident in the first evaluation in 2016/17 (Table 3); this pathogen is favored by low humidity and mild temperatures (AMORIM et al., 2016). However, from the beginning of December 2016, conditions were favorable (Figure 1) to the development of Asian rust, mildew, septoriosis and cercosporiosis, mainly due to frequent precipitation and increase in mean temperature (SARTO et al., 2013). In general, the conditions for *P. pachyrhizi* soybean infection are temperatures in the range 10 ºC to 27.5 ºC (optimum temperature between 20 ºC and 23 ºC) and wet periods of more than 6 hours (MELCHING et al., 1989). In 2015/16, Asian rust incidence was observed at 42 days after emergence (DAE), with an approximate percentage of 5% of infected leaves in all plots (Table 3). In the treatment without application of fungicides, the disease progressed to 41.18% (63 DAE), 82.81% (81 DAE) and 100% (95 DAE).

Table 3. Asian rust, powdery mildew and mildew incidence (%) in soybean, cvs. NS 5445 IPRO and BMX Ativa, from certified and uncertified seeds, with or without fungicide (Fun.) aplication, at 42 (1 st evaluation – ev.), 63 (2 st ev.), 81 (3 st ev.) and 95 (4 st ev.) Days After Emergence (DAE) in 2015/16 crop season, and 40 (1 st ev.), 58 (2 st ev.), 74 (3 st ev.) and 92 (4 st ev.) DAE in 2016/17 crop season.

Tratamentos	2015/16				2016/17			
	1st ev.	2 st ev.	3 st ev.	4 st ev.	1 st ev.	2 st ev.	3 st ev.	4 st ev.
	42 DAE	63 DAE	81 DAE	95 DAE	40 DAE	58 DAE	74 DAE	92 DAE
	Asian rust (%)							
NS 5445	5.2 a[1]	26.5 a	60.7 a	95.2 a	-	-	37.7 b	61.9 b
BMX Ativa	5.3 a	28.7 a	62.2 a	97.2 a	-	-	45.0 a	67.2 a
Certified	5.2 a	27.1 a	61.9 a	96.2 a	-	-	40.0 a	62.8 a
Uncertified	5.3 a	28.1 a	61.0 a	96.1 a	-	-	42.7 a	66.2 a
With Fun.	5.1 a	14.0 b	40.1 b	92.4 b	-	-	0.0 b	34.1 b
Without Fun.	5.3 a	41.2 a	82.8 a	100.0 a	-	-	82.7 a	95.0 a
C.V. (%)	14.7	15.2	10.9	3.9	-	-	14.7	9.5
	Powdery mildew (%)							
NS 5445	-	10.7 a	38.6 a	41.0 a	10.9 a	10.9 a	31.2 b	56.2 a
BMX Ativa	-	12.7 a	38.1 a	41.7 a	12.1 a	12.1 a	43.1 a	55.3 a
Certified	-	11.1 a	37.6 a	41.6 a	11.2 a	11.5 a	35.6 a	55.3 a
Uncertified	-	12.4 a	39.1 a	41.1a	11.8 a	11.9 a	38.7 a	56.2 a
With Fun.	-	0.0 b	23.2 b	26.5 b	0.0 b	0.0 b	0.6 b	26.6 b
Without Fun.	-	23.5 a	53.4 a	56.2 a	23.0 a	23.0 a	73.5 a	85.0 a
C.V. (%)	-	25.3	10.9	11.9	16.5	16.5	15.7	18.7
	Mildew (%)							
NS 5445	36.0 a[1]	43.1 a	81.5 a	82.4 a	39.1 a	64.7 a	81.5 a	87.5 a
BMX Ativa	32.6 a	39.7 a	78.3 a	82.7 a	39.1 a	60.9 a	82.5 a	86.6 a
Certified	33.7 a	42.8 a	78.6 a	82.7 a	39.6 a	61.2 a	83.1 a	88.1 a
Uncertified	34.9 a	40.0 a	80.9 a	82.3 a	39.6 a	64.4 a	80.9 a	85.9 a
With Fun.	34.6 a	38.7 b	78.0 a	81.2 a	38.7 a	58.4 b	77.2 b	81.2 b
Without Fun.	34.1 a	44.1 a	81.6 a	83.8 a	39.4 a	67.2 a	86.9 a	92.8 a
C.V. (%)	14.3	12.7	7.2	5.9	12.1	11.5	11.4	9.5

[1] Averages follow by the same lower case letter in column do not differ by Tukey´s test ($p \leq 0.05$).

Regarding treatments with fungicide application, the presence of Asian rust was observed at 42 DAE, with an incidence of 5.15%. In the other evaluations, this percentage increased gradually when compared to the plots with no fungicide application: 14% incidence (63 DAE), 40.06% (81 DAE) and 92.37% (95 DAE). For Asian rust incidence, there was no significant difference for seed origin and cultivars (Table 3).

In 2016/17, Asian rust incidence was observed only after the third evaluation (74 DAE), which can be explained by unfavorable meteorological conditions (Figure 1) for the pathogen at the beginning of the crop cycle. According to Godoy et al. (2016) in a study conducted in Brazil, losses in productivity due to Asian rust vary among crops. In addition, the occurrence of a severe winter with regard to temperatures, eliminated alternative hosts, such as volunteer soybean plants. Also in 2016/17, cv. BMX Ativa showed greater sensitivity to *Phakopsora pachyrhizi*, reaching a 5.3% incidence higher than cv. NS 5445 IPRO (Table 3). With fungicide treatment, the incidence of Asian rust in the final evaluation (92 DAE) was limited to 34.1%, however, without application of fungicide, a 60.9% incidence was observed.

Regarding the incidence of powdery mildew, there was no difference as a result of seed origin. In the third evaluation of the 2016/17 crop season, cv. BMX Ativa presented an incidence of 11.9% higher than cv. NS 5445 (Table 3). In the final evaluation, plots without application of fungicides presented 56.18% incidence of powdery mildew in 2015/16 (95 DAE) and 85% (92 DAE) in 2016/17. In the plots with the application of fungicides, the percentage incidence remained lower in both crops (26.5% in 2015/16 and 26.6% in 2016/17). Gallotti et al. (2005) also reported a 30% reduction in the incidence of powdery mildew after application of fungicides, however, there was an increase in the severity of this disease during pod formation and grain filling. In this sense, cultivars with different degrees of resistance differ in response to the application of fungicides for the control of powdery mildew (BALARDIN, 2004).

According to Almeida et al. (2017), chemical control of foliar diseases in soybean depends on the cultivar and the sowing season. In the second evaluation in 2015/16, there was a higher incidence of mildew in the treatments without fungicide application in both cultivars. However, in the next harvest, plots treated with fungicides demonstrated a lower pathogen incidence in all evaluations. The other variables did not present a statistically significant difference (Table 3).

A high incidence of septoriosis was demonstrated in the plots without fungicides application, and, in the final evaluation, the application of fungicides had reduced the incidence to 10.5% in 2015/16 and to 30.6% in 2016/17. This disease incidence did not differ between cultivars, however, but according to seed origin, with a 9.3% higher incidence observed in uncertified seeds in 2016/17, compared to certified seeds (Table 4).

In 2015/16, in plots without fungicide application there was a higher cercosporiosis incidence (77.8%), for uncertified seeds (77.2%) and cv. BMX Ativa (76.2%). This behavior was observed in the same cultivar in 2016/17 (Table 4). The lower cercosporiosis incidence in NS 5445 cultivar may be due to plant architecture, allowing a faster leaf drying rate and shorter development cycle (maturation group 5.4), in relation to cv. BMX Ativa which has a slightly longer development cycle (maturity group 5.6) (CARNIEL et al., 2014).

Cercosporiosis, caused by the fungus *Cercospora kikuchii*, is usually accompanied by the incidence of septoriosis, the etiological agent being *Septoria glycines*. These pathogens, in addition to being able to survive in cultural remains, can also be transmitted by seeds, infecting them or infesting them and causing yield losses of up to 30% (LEMES et al., 2015; AMORIN et al., 2016). In a study carried out by Embrapa on soybean seed quality and commercial grains in Brazil in the 2014/15 harvest, it was demonstrated that the most frequent pathogen to occur in lots of soybean seeds was *Cercospora kikuchii*, the causal agent of seed spot purple. This pathogen survives in the cultural remains, infects the plants and, together with *Septoria glycines*, can cause the so-called “ECD’s” (end-of-cycle diseases) (LORINI, 2016). Guerzoni et al. (2003) found that most of the fungicides used to control Asian rust also control septoriosis and cercosporiosis.

Table 4. Septoriosis and cercosporiosis incidence (%) in soybean, cvs. NS 5445 IPRO e BMX Ativa, from certified and uncertified seeds, with or without fungicide (Fun.) aplication at 42 (1 st evaluation – ev.), 63 (2 st ev.), 81 (3 st ev.) and 95 (4 st ev.) Days After Emergence (DAE) in 2015/16 crop season, and 40 (1 st ev.), 58 (2 st ev.), 74 (3 st ev.) and 92 (4 st ev.) DAE in 2016/17 crop season.

Tratamentos	2015/16				2016/17			
	1st ev.	2 st ev.	3 st ev.	4 st ev.	1 st ev.	2 st ev.	3 st ev.	4 st ev.
	42 DAE	63 DAE	81 DAE	95 DAE	40 DAE	58 DAE	74 DAE	92 DAE
	Septoriosis (%)							
NS 5445	-	-	26.1 a[1]	38.7 a	-	-	55.0 a	56.9 a
BMX Ativa	-	-	27.2 a	39.4 a	-	-	56.6 a	58.1 a
Certified	-	-	26.3 a	37.9 a	-	-	56.9 a	52.9 b
Uncertified	-	-	27.0 a	40.2 a	-	-	54.7 a	62.2 a
With Fun.	-	-	20.9 b	33.8 b	-	-	46.9 b	42.2 b
Without Fun.	-	-	32.4 a	44.3 a	-	-	64.7 a	72.8 a
C.V. (%)	-	-	14.0	11.5	-	-	17.3	16.3
	Cercosporiosis (%)							
NS 5445	-	25.1 b	68.6 a	71.7 b	-	-	32.3 a	51.1 b
BMX Ativa	-	34.9 a	66.4 a	76.2 a	-	-	33.1 a	56.8 a
Certified	-	27.8 b	66.6 a	70.7 b	-	-	24.6 b	50.1 b
Uncertified	-	32.1 a	68.4 a	77.2 a	-	-	33.4 a	57.8 a
With Fun.	-	21.3 b	62.4 b	70.1 b	-	-	27.5 b	50.3 b
Without Fun.	-	38.6 a	72.6 a	77.9 a	-	-	38.0 a	57.3 a
C.V. (%)	-	16.9	10.7	5.9	-	-	14.8	11.8

[1]Averages follow by the same lower case letter in column do not differ by Tukey´s test ($p \leq 0.05$).

Lopes et al. (1998), analyzing the effect of the fungicide difenoconazole + propiconazole, verified the control of *Septoria glycines* and *Cercospora kikuchii*. Godoy and Canteri (2004) observed a reduction of up to 54.5% in the severity of powdery mildew and cercosporiosis when three fungicide applications were performed after R3 stage. According to Sarto et al. (2013), in this crop the pathogens present had different behavior at each harvest, being influenced mainly by the environmental conditions. Therefore, the established patossystems in the soybean crop are directly related to meteorological conditions of each year. In addition, the use of certified seeds of known origin, with sanitary and physiological quality can provide increases in productivity, given that this is a determining input for the definition of crop potential and that it can act as a disseminating agent of potential pathogens to soybean crops.

Conclusions

Considering the conditions under which the experiment was conducted, it was concluded that:

1. Seeds with certified origin stand out in terms of germination and vigor.

2. The use of certified seeds combined with the application of fungicides provides greater productivity.

3. The number of grains per plant is higher in plants derived from certified seeds and receiving application of the fungicides trifloxystrobin + prothioconazole and azoxystrobin + benzovindiflupir.

4. The origin of the seeds is not a determinant for the incidence of Asian rust, powdery mildew and mildew, but for end-of-cycle diseases, such as septoriosis and cercosporiosis.

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