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International Journal of Current Research
Vol. 8, Issue, 09, pp.38398-38401, September, 2016

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

PERFORMANCE OF RESISTANT SOYBEAN TO ASIAN RUST IN DIFFERENT ENVIRONMENTS IN RS

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ARTICLE INFO

Article History:
Received 05th June, 2016
Received in revised form
20th July, 2016
Accepted 25th August, 2016
Published online 30th September, 2016

Key words:

Environments, Glycine max L. Merrill, Rusticity, Grain yield.

ABSTRACT

This study aimed to test performance resistant soybean to Asian rust in different environments of Rio Grande do Sul. The experiment was conducted in the agricultural year 2013/2014 in five producer of soybeans regions of Rio Grande do Sul. The experiment was conducted in randomized block design, arranged in four replicates. Data were subjected to variance analysis by F test, and the means were performed comparing by Duncan test at 5% probability of error, in the Genes statistic program. Soybean rust resistant does not have the same performance at all cultivation environments, indicating that a narrower agricultural zoning should be effected. The best performance of soybean rust resistant is expressed in Derrubadas, under the variable grain yield, grain yield per plant, number of branches and number of pods with 2 and 3 grains.

Citation: Alan Junior de Pelegrin, Ivan Ricardo Carvalho, Maicon Nardino, *et al.* 2016. "Performance of resistant soybean to Asian rust in different environments in Rs", *International Journal of Current Research*, 8, (09), 38398-38401.

INTRODUCTION

Soybean is a major oilseed produced and consumed in the world, and is the main protein source that is an essential constituent for the manufacture of feed for animals and for human consumption, it is also used as raw material for biodiesel extraction in Brazil (Brum *et al.,* 2005). Brazil is a major producer and the largest exporter of soybeans. Brazilian production reached the 2013/14 season the volume of 86,120,800,000 tons. The Rio Grande do Sul is responsible for third largest grain production in the country, behind only Mato Grosso and Paraná (Conab, 2015). Despite the growing increase in production and soybean yield, the incidence of disease is a limiting factor to the production of soybean potential. Asian soybean rust is considered the main disease, because of having high potential for damage, where the main damage caused by the disease is early defoliation of the plant preventing the occurrence of the complete formation of the grains. The earlier defoliation occurs, the smaller will be grains size and consequently, lower the grains yield (Merching *et al.,* 1989). The extent of damage that the pathogen can cause depends on the moment it enters the culture, climate conditions favorable to its multiplication, resistance/tolerance and cultivar cycle (Almeida, 2005). With reducing the efficiency of fungicides registered for the control of Asian soybean rust (*Phakopsora pachyrhizi*) to search for soybean genotypes with increased tolerance/resistance to pathogen attack has been a major searched tool for genetic improvement, in order to reduce the impacts this disease causes in the soybean yield (Marques *et al.,* 2014). The INOX® technology is relatively new and presents among the main features resistance to Asian soybean rust (ASR). Launched by MT Foundation in 2008 in the Cerrado region (Hiromoto and Camacho, 2008), only in the agricultural year 2011/2012, genotypes with this technology began to be cultivated in southern Brazil. The genotype x environment interaction (GxE) is defined as the differential behavior of genotypes depending on the environmental diversity. Within this context, edaphoclimatic conditions associated with cultural practices, the occurrence of pathogens and other variables that affect the development of plants characterize the environment.

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From this, it can be considered that the environment is made up of all the factors that affect the development of plants that are not genetic in origin (Borém and Miranda, 2009). This study aimed to evaluate the performance of soybean resistant to Asian rust in different environments in the state of Rio Grande do Sul.

MATERIALS AND METHODS

The experiment was conducted in the agricultural year 2013/2014 in five producer soybean regions of Rio Grande do Sul. The experiment realization environments were: Independência, located in the coordinates 27°51'18"S, 54°17'13"W, altitude of 315m and soil type dystrophic Red Latosol; Tapera, located in the coordinates 28°42'11"S and 52°51'25"W, altitude of 381m and soil type distroferric Red Latosol; Derrubadas, located in the coordinates 27°16'63"S and 53°47'33"W, altitude of 430m and soil type Alfisol Eutroferric argisolic; Frederico Westphalen, located in the coordinates 27°39'05"S and 53°42'94"W, 490m altitude and soil type dystrophic Red Latosol; and Pelotas, located in the coordinates 31º52'00"S and 52º21'24"W, altitude of 13m and soil type distroferric Yellow Red Argissoil. The characterization of the environments followed the soil classification proposed by Embrapa (2006), and climatic classification it is the cfa type, as proposed by Koppen. The experiment was conducted in a randomized block design, arranged in four repetitions. The tested environments were the cities of Frederico Westphalen, Derrubadas, Tapera, Independência e Pelotas. To experiment conduction was used the soybean cultivar TMG 7161 RR, which has INOX® technology and is characterized for being an indeterminate growth habit cultivar and physiological maturity group 5.9. The seeding density used was 250,000 seeds per hectare.

Experimental units were composed of five rows of three meters, with line spacing of 0.45 meters, totaling a plot area 6.75 m². To compose the useful area of the plot were considered the three central rows, discarding 0.5 m from each end, with a total floor area of 2.70 m². The experiment was allocated in areas previously cultivated with wheat during the winter. Held early desiccation of the areas and the grooves were made with the use of no-till machine seeder, at the moment there was the fertilization of 300 kg ha^{-1} NPK 02-25-25 formulation. Seeding was done manually, and the seeds placed at a depth of three to five centimeters. The seeding density used was recommended by companies of each cultivar, respecting the time of sowing and macro producer soybean region, and carried out between November 15th and 19th, 2013. For the purposes of the experiment, all environments and experimental units received the same cultural practices, adopting preventive management to control weeds, pests and diseases. From this, the control was performed with use of recommended products for culture. The harvest of the experiment was conducted during the period from March 25th to April 5^{t}h, 2014. The experimental units were harvested manually, track to carrying out the grains with the aid of an electric grain thresher. Variables of agronomic interest evaluated based on the useful area of the plot were: grain yield - RG, extrapolated results for kg ha^{-1} from the total grain mass each experimental unit, corrected to 13% humidity; grain yield per planta – GYP, the grain mass per planta was weighted, expressed in g. Thousand kernel weight - TKW, measured by manual count of eight repetitions of 100 seeds, expanding to the thousand kernel weight, results in grams (g). Yield components were evaluated from the collection of 10 representative plants of the useful plot area: kernel mass per plant - KMP, the measured mass of grains per plant, results in g. Number of pods on the stem - NLS, as the number pods in stem per plant. Plant height - PH, measured from the base of the plant with the ground until the end of the main stem of the plant, results in centimeters (cm). First pod insertion height - FPIH, measured from the base of the plant with the ground until the first legume, results in cm. Number of pods in branches - NPB, as the total number of pods present in branches per plant. Number of branches - NB measured by counting total branching greater than 10 cm present in a plant. Number of pods with one grain - NPAG, obtained by counting the totality pods with a grain present in a plant. Number of pods with two grains - NPTG, obtained by counting of all pods with two grains present in a plant. Number of pods with three grains - NPHG, obtained by counting of all pods with three grains present in a plant. Data were subjected to variance analysis by F test. It conducted comparison of means by Duncan test at 5% probability of error in the computer program Genes (Cruz, 2013).

RESULTS AND DISCUSION

The analysis of variance revealed meaningfulness by F test for the variables grain yield, grain yield per plant, thousand kernel weight, plant height, first pod insertion height, number of branches, number of pods in branches, number of pods with two grains, number of pods with three grains. We found no meaningful differences for the variables number of pods on the main stem and number of pods with a grain. Among the five environments evaluation, Derrubadas obtained higher grain yield, whereas in Pelotas were found smaller magnitudes for this variable (Table 1). From this, it can be seen that despite the TMG 7161 RR genotype have agricultural zoning for all environments (BRAZIL, 2014), their behavior was different among them.

Table 1. Average results for grain yield - GY (kg ha^{-1}), grain yield per plant - GYP (g), thousand kernel weight - TKW (g), plant height - PH (cm), first pod insertion height - FPIH (cm) and number of pods on the main stem - NPS for different environments

Envionment	GY	GYP	TKW	PH	FPIH
Independência	3334.60 b	13.95 b	141.17 bc	81.10 c	23.65 abc
Tapera	3450.80 b	13.80 b	146.97 bc	107.96 ab	29.87 a
Derrubadas	4146.40 a	18.32 a	134.08 c	91.75 bc	21.92 bc
F. Westphalen	3643.50 ab	14.87 ab	151.72 ab	119.63 a	28.20 ab
Pelotas	2242.40 c	11.26 b	166.62 a	89.35 bc	18.92 c
CV (%)	11.1	16.12	6.9	14.19	17.22

*Means followed by the same letter (a) in the column are not statistically different to Duncan at 5% probability of error.

Borém and Miranda (2009) attribute this behavior to the genotype x environment interaction, that is the differential behavior exhibited by genotypes depending on the environmental diversity, which is influenced by edaphoclimatic conditions associated with cultural practices, the presence of pathogens and other factors that affect plant development. As Rezende and Carvalho (2007), environmental factors, humidity, temperature and photoperiod, determine the genotype used in a region and have direct influence on the expression of the maximum genetic potential of the plant. In the same way, for the kernel mass per plant, higher magnitudes were found in Derrubadas. Inferring that KMP possessed positive correlation with grain yield, corroborating Dalchiavon and Carvalho (2012), which showed that the grain yield per plant and the number of pods per plant are associated directly with the soybean productivity, so that these traits may be successfully used to estimate the soybean yield.

For thousand kernel weight trait, superior results were found in Pelotas. This income component is strongly affected by water availability during the development phase and grain filling. According Pandey and Torrie (1973), the average kernel weight is genetically determined, but influenced by the environment. In corroboration of this, studies for applying fluid restriction in soybean plants, the grain filling stage, Sionit and Kramer (1977) observed a decrease in hundred kernel weight. When water restriction occurs about a month after flowering, studies show that reduction occurs in grain size, and if there is the flowering period leads to a decrease in the number of pods thus increasing the size of grains (Momen *et al.,* 1979). In studies by Egli *et al.,* (1983), it was shown to increase hundred grains weight when the water restriction was applied prior to the reproductive stage R5, and reduction was observed when the stress was from the R5 stage. For plant height, the highest values were found in Frederico Westphalen, obtaining 119.63 cm, while the lowest results are found in Independência, 81.10 cm. According to Garcia *et al.,* (2007), it is desirable that final plant height is above 60 cm, because it helps to reduce grain loss in harvesting operation. Being able to infer that, although there were differences among environments in all, the genotype study showed plant height above the minimum level cited by the author. However, Souza *et al.,* (2013) emphasize that more compact plants, more balanced can be more efficient photosynthesis, whereas the research in soybean have search smaller plants, and more balanced architecture that is able to withstand the great number of pods and grains to harvest time (Singh, 2001).

Already the higher first pod insertion height was observed in Tapera, among environments. Moreover, the smaller height, among five environments studied, was observed in Pelotas. However, all environments presented the first pod insertion height, within the time recommended by EMBRAPA (1996), which describe that first pod insertion height higher than 12 cm, minimizing crop losses. There were no significant differences in the number of pods on the main stem to the TMG 7161 RR genotype in five different environments in the study. Corroborating Bahry *et al.,* (2011), which studied the nitrogen fertilization in reproductive stages on soybean agronomic development, found no significant difference in the dose factor and nitrogen application time on the number of pods on the main stem. When analyzing number of branches (NB) trait (Table 2), it can be seen that in Derrubadas obtained the highest magnitude, reaching 3.17 branches per plant. Navarro Junior and Costa (2002), point out that the morphological traits number of branches per plant, length of branches and number of fertile nodes relate directly to the plant production potential, they represent most photosynthetically active area and also potentially productive through the number of environments for development of flower primordia. From this it can be inferred that the largest number of branches reached in Derrubadas contributed to this environment was expressed higher magnitude to grain yield. Corroborando com Mauad *et al.,* (2010), os quais, em estudos com densidade de semeadura de soja, atribuem as variações no número de ramos da soja, à competição que ocorre entre as plantas de soja pelos fatores de crescimento do ambiente, especialmente pela luz, onde em maiores densidades de semeadura, em função do número excessivo de plantas na linha, ocorre menor disponibilidade de fotoassimilados para o crescimento das ramificações, sendo estes, preferencialmente destinados ao crescimento da haste principal. In Frederico Westphalen smaller magnitudes of branches per plant were observed, whereas in the same environment were found larger plant height values. Corroborating to Mauad *et al.,* (2010), that in studies with soybean seed density, attribute the variations in the number of soybean branches, to competition occurring between the soybean plants by environmental growth factors, especially by light, where at higher densities sowing, depending on the excessive number of plants in a row, is smaller availability of assimilates to the growth of branches, and preferably used for the growth of the main stem.

Table 2. Average results to number of branches - NB, number of pods in branches - NPB, number of pods with 2 and 3 grains for the different environments

Environment	NB	NPB	Number of pods	
			2 grains	3 grains
Independência	2.85 ab	12.80 a	18.72 b	18.57 b
Tapera	1.93 bc	7.50 b	17.55 b	19.01 b
Derrubadas	3.17 a	16.80 a	23.52 a	25.97 a
F. Westphalen	1.12 c	5.00 b	17.22 b	18.77 b
Pelotas	2.60 ab	13.09 a	14.35 b	16.05 b
CV (%)	26.5	30.99	16.58	18.25

*Means followed by the same letter (a) in the column are not statistically different to Duncan at 5% probability of error.

For number of pods in the branches, the Independência, Derrubadas and Pelotas expressed themselves superior to other environments, whereas if not different. Similarly, Gubiani (2005) evaluating the response of soybean sowing dates and plant arrangement, found differences in the number of pods in the branches. Regarding the number of pods per plant with 1, 2 and 3 grains, can contact in Derrubadas was the largest number of grains with 2 and 3 grains, reaching magnitudes of 23.52 and 25.97 pods per plant, respectively. However, there were no significant differences in the number of pods with 1 grain. This response may be related to environmental and climatic conditions occurred in Derrubadas environment, have enabled the TMG 7161 RR genotype express a greater magnitude the number of grains per pod, as Heiffing (2002) believes that the number of grains per pod is a feature typically genetics.

McBlain and Hume (1981) point out that the number of grains per pod is heavily influenced by the fact that modern cultivars are selected for the formation of 3 ovules per pod.

Conclusion

Resistant soybean to rust does not have the same performance among all cultivation environments, possibly because the environments are contrasting edaphoclimatic conditions and even a resistant cultivar has swings for the evaluated traits, indicating that a more restrictive agricultural zoning should be made effective. The performance of resistant soybean to Asian rust (*Phakopsora pachyrhizi*) is best expressed in Derrubadas under grain yield, grain yield per plant, number of branches and number of pods with two and three grains.

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