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ANALYSIS OF PROGENY-ENVIRONMENT INTERACTION WITH SEEDLING TUBERS OF TRUE POTATO SEED (*Solanum tuberosum* L.) IN CUBA

Análisis de la interacción progenie-ambiente con minitubérculos a partir de semilla sexual de papa (*Solanum tuberosum*, L.) en Cuba

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ABSTRACT. During crop years 2007-2008 and 2008-2009 at three locations (National Institute of Agricultural Sciences-Mayabeque , Agricultural Enterprise "V. Lenin"-Matanzas and Agricultural Enterprise "La Cuba"-Ciego de Ávila), 13 progenies from seedling tubers were evaluated and three witnesses varieties (Romano, Spunta and Cal White). Number of tubers per plant, yield per hectare (t ha^{-1}) and incidence of spots on the foliage by the fungus *Alternaria solani* Soraeur were recorded. The data were processed by analysis of variance, and adjusted with additive main effects and multiplicative interaction model (AMMI) to the characters which was significant genotype environment interaction was adjusted. The sexual progeny Lajera x 6-3-98 were stable for tuber number and yield in six environments studied. The Lajera x 6-3-98, Lajera x 9-80-98, progenies were stable for yield and average tuber mass in the six environments studied. The progeny Samila x 2-130-98, Yara x 1-10-96, Yara x 9-80-98, Atlantic x Aninca y Samila x 6-3-98, were the most unstable for the three studied traits but specific adaptation in each locality. These contrasts in the agronomic performance of the progeny of sexual seed suggest the need to evaluate the materials in each production area.

Key words: potato, sexual progeny, cultivar, environment, stability, yield

RESUMEN. Durante las campañas agrícolas 2007-2008 y 2008-2009 en tres localidades (Instituto Nacional de Ciencias Agrícolas-Mayabeque, Empresa Agropecuaria "V. Lenin"-Matanzas y Empresa Agropecuaria "La Cuba"-Ciego de Ávila), se evaluaron 13 progenies de semilla sexual de papa y tres cultivares testigos (Romano, Spunta y Cal White). Se registraron número de tubérculos por planta, rendimiento por hectárea (t ha^{-1}) e incidencia de manchas en el follaje del hongo *Alternaria solani* Soraeur. Los datos fueron procesados mediante un análisis de varianza de clasificación doble, y se ajustó el modelo de efectos principales aditivos e interacciones multiplicativas (AMMI) a los caracteres donde resultó significativa la interacción genotipo-ambiente para el ajuste. La progenie Lajera x 6-3-98 fue estable para el carácter número de tubérculo y rendimiento, en los seis ambientes estudiados. Las progenies Lajera x 6-3-98, Lajera x 9-80-98, fueron estables para el rendimiento y para la masa promedio del tubérculo en los seis ambientes. Las progenies Samila x 2-130-98, Yara x 1-10-96, Yara x 9-80-98, Atlantic x Aninca y Samila x 6-3-98, fueron las más inestables para las características estudiadas pero con adaptación específica en cada localidad. Estos contrastes en el comportamiento agronómico de las progenies de semilla sexual sugiere la necesidad de evaluar los materiales en cada zona de producción.

Palabras clave: papa, progenie sexual, cultivar, ambiente, estabilidad, rendimiento

INTRODUCTION

Potato (*Solanum tuberosum*) is a plant belonging to the genus *Solanum*, is native from South America and cultivated worldwide for its edible tubers. It is one of the most basic food crop plantation area expands in developing countries, this should be its broad adaptation to its high yield per unit area and time, its

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high nutritional value and various forms of use and processed products thereof are obtained (1).

This crop is produced commercially by seed tubers; however, it can also do it sexually with true seed or botany (SB), which is exploited primarily for the genetic improvement of the species, but also, as planting material to produce seed and consumption potatoes(2).

Seed tubers are usually the most expensive input in potato production, and in Cuba it represents between 40 and 50 % (1200-1500 USD ha^{-1}) thereof, considering the price of the SB in the international market, it can be reduced by way of seed between 80 and 90 % per hectare.

The cultivation is influenced by weather elements which influence the growth, development, yield and quality of potatoes. These are mainly the soil temperature and air, solar radiation, photoperiod, soil moisture and evapotranspiration (3).

The evaluation of genotypes in different locations and over time is important to estimate differential genotypic and phenotypic responses under different environmental conditions; measuring its genotype-environment interaction gives an idea of the phenotypic stability of varieties to environmental fluctuations (4), this analysis has been used successfully to select desirable genotypes potato (5).

Potato, through sexual reproduction results in highly heterogeneous offspring, because clones are heterozygous, as a result, each seed is genetically different and therefore the tuber production also possesses high variability. This would be an obstacle to the use of SB technology, but would provide greater stability and adaptation of these to different environments.

Taking into account the above arguments the aim of this study was to evaluate the agronomic performance, stability and adaptability of SB potato progenies in the three most important locations for cultivation for two years and select materials in relation to genotype-environment interaction.

MATERIALS AND METHODS

During the 2008-2009 crop years and 2009-2010 in three locations (National Institute of Agricultural Sciences “INCA” -Mayabeque, Agricultural Company “Lenin” - Matanzas and Agricultural Enterprise “The Cuba” - Ciego de Avila), 13 progenies of SB (9-80-98 -PL, Atlantic x 06/03/98; Atlantic x Aninca; Gorbea x 10/01/98; Lajera x 03/06/98; Gorbea x 03/06/98; Lajera x 9-80-98; Samila x 2 -130 to 98; Samila x 06/03/98; Samila-PL; Yara x 01/10/98; Yara x 9-80-98 Yara-PL) were evaluated and three witness cultivars (Cal White, Roman and Spunta).

F1 minitubers obtained in beds of progeny and seed tubers 28-35 mm caliber certificates for the control cultivars were used as material planted. The planting dates in each place for the first and second season were December 12th, 15th and 17th and December 10th, 12th and 15th, respectively.

In all sites, experiments were carried out in a completely randomized design with four replications blocks. Each plot measured 2,25 x 1,8 m with two rows separated by 90 cm between them and 25 cm between plants. The recommended crop management cultural practices were adopted (6).

In each place the following data were reported: 1. Number of tubers per plant, five randomly selected plants in each plot were harvested and the number of tubers were counted. 2. Yield (t ha^{-1}) yield (kg) per plant by the total number of plants in a hectare (44444) and divided by 1000; 3. Impact of spots on the foliage of infection by the *Alternaria solani* (Ellis and Martin) Jones and Grout fungus is performed at 65 days after planting, for which the scale of 9 degrees proposed by Horsfall and Barrat cited by Estevez (7) was used, where the degree 1- without spots in the foliage and degree 9- all dead leaves foliage.

Statistical analysis

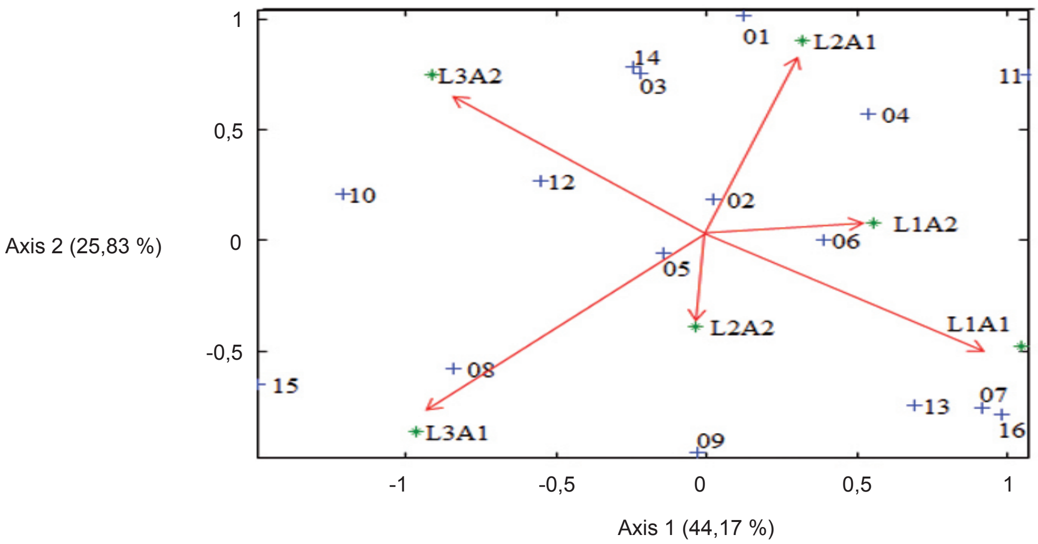
Data were processed through a variance analysis of double classification and applied the multiple range test of Duncan at 5 % using SPSS (16.0) statistical package. For characters where significant genotype-environment interaction was detected therein by AMMI model was analyzed, the effective interaction AMMI multiplicative and additive main effects (8), for which the SAS program was used, was adjusted.

RESULTS AND DISCUSSION

When analyzing corresponding variance, an interaction among progenies and between progenies per environment significant to character for the number of tubers per plant was , total yield (t ha^{-1}) and average mass of the tuber, which justified AMMI model fit.

In the Biplot graph (Figure 1, 2 and 3) genotypes were represented by a point and environments, as vectors originating at point 0,0. Closer genotypes that are located to the center of the graph, they less answer to environmental variations, therefore, they are the most stable. Meanwhile, the ones that are farther from the center are considered the major contributors to the interaction, which is most responsive to environmental stimuli.

In Figure 1, both shafts (1 and 2) accounted for 70,0 % of the genotype-environment interaction for the number of tubers per plant, shafts 1 explains 44,17 % of the interaction, while the shaft 2, the remaining 25,83 %.



1= 9-80-98-PL, 2 = Atlantic x 6-3-98, 3= Atlantic x Aninca, 4= Cal White (T), , 5= Gorbea x 1-10-96, 6= Lajera x 6-3-98, 7= Gorbea x 6-3-98, 8= Lajera 1=9-80-98-PL, 2=Atlantic x 6-3-98, 3=Atlantic x Aninca, 4=Cal White (T), , 5=Gorbea x 1-10-96, 6=Lajera x 6-3-98, 7=Gorbea x 6-3-98, 8=Lajera x 9-80-98, 9=Romano (T), 10=Samila x 2-130-98, 11=Samila x 6-3-98, 12=Samila-PL, 13=Spunta (T), 14=Yara x 1-10-96, 15=Yara x 9-80-98, 16=Yara-PL. L1A1=Locality INCA (Mayabeque), agricultural season 2008-2009, L1A2=Location INCA (Mayabeque), agricultural season 2009-2010, L2A1=Locality Agricultural Enterprise V. Lenin (Matanzas), agricultural season 2008-2009, agricultural season 2008-2009, L2A2=Localidad Agricultural Enterprise V. Lenin (Matanzas), agricultural season 2009-2010, L3A1=Localidad Agricultural Enterprise La Cuba (Ciego de Ávila) locality, L3A2=Locality Agricultural Enterprise La Cuba (Ciego de Ávila), agricultural season 2009-2010

Figure 1. Biplot representation the number of tubers per plant corresponding to 16 genotypes (axis 1 and 2) in six environments (vectors) by AMMI model

Progenies 2 (Atlantic x 03/06/98), 5 (Gorbea x 06/03/98) and 6 (Lajera x 03/06/98) were the most stable for this character in the six environments studied.

Seen in this same figure, a positive response to environmental stimuli in L3A1, progenies 8 (Lajera x 9-80-98), 15 (Yara x 9-80-98) and witness farming 9 (Romano) and in L2A1 negatively. Moreover, progenies 7 (Gorbea x 03/06/98) 16 (Yara- PL) and farming witness 13 (Spunta) interacted positively in L1A1 environment but negatively in L2A1 and L3A2. Also responded positively progenies 1 (9-80-98-PL), 3 (Atlantic x Aninca), cultivar Witness # 4 (Cal White), 11 (Samila x 6/3/98) and 14 (Yara x 01/10/98) but the environment in L2A1 and L3A1 negatively. Finally progeny 10 (Samila x 2-130-98) interacted positively in L3A2 environment and negatively in L1A1 one.

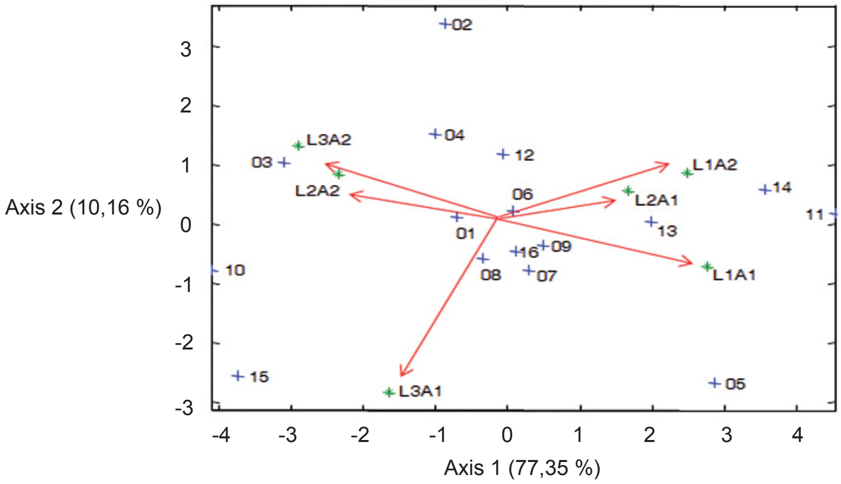
Results suggest the capacity of a group of progenies with adaptation to all environments and another group studied to adapt to specific environments. These results indicate that the progeny test in multiple sites can identify progenitors producing more widely adapted progenies, and on the other hand, selecting superior progenies with general and specific adaptation.

Similar results indicated Sharma *et al*. (9), who established that the localities, locality- genotypes interaction genotype showed significant variations for the number of minitubers per plant two growing seasons (optimal and delayed) in the Himalayas.

In Figure 2, both shafts (1 and 2) accounted for 87.51 % of the genotype-environment interaction to yield (t ha^{-1}), the shaft 1 explains 77.35 % of the interaction, as the shaft 2, the remaining 10.16 %.

Progenies 3 (Atlantic x Aninca), 10 (Samila x 2-130-98) and 2 (Atlantic x 03/06/98) responded positively in the L2A2 and L3A2 environments, but negatively in L1A1 and L1A2 except progeny 2 did in L3A1. Meanwhile, 15 (Yara x 9-80-98) interacted positively in L3A1 and negatively in L1A2. Progenies 11 (Samila x 6/3/98) and 14 (Yara x 10/01/96) had a positive response in L1A2 and L1A1 and negatively in L3A2 and L2A2 responded. Progeny 5 (Gorbea x 1/10/96) interacted positively in L1A1and negatively in L3A2 and L2A2.

Furthermore, progenies 1 (9-80-98-PL), 6 (Lajera x 03/06/98), 7 (Gorbea x 06/03/98), 8 (Lajera x 9-80-98), 16 (Yara-PL) and the witness cultivart 9 (Romano) were the most stable in performance, which could indicate that these genotypes carry genes stability in these media, which may be present regardless of the origin of genotype (PL, hybrids or cultivars).



1=9-80-98-PL, 2=Atlantic x 6-3-98, 3=Atlantic x Aninca, 4=Cal White (T), , 5=Gorbea x 1-10-96, 6= Lajera x 6-3-98, 7=Gorbea x 6-3-98, 8=Lajera x 9-80-98, 9=Romano (T), 10=Samila x 2-130-98, 11=Samila x 6-3-98, 12=Samila-PL, 13=Spunta (T), 14=Yara x 1-10-96, 15=Yara x 9-80-98, 16=Yara-PL.L1A1=Locality INCA (Mayabeque), agricultural season 2008-2009, L1A2=Locality INCA (Mayabeque), agricultural season 2009-2010, L2A1=Locality Agricultural Enterprise V. Lenin (Matanzas), agricultural season 2008-2009, agricultural season 2008-2009, L2A2=Locality Agricultural Enterprise V. Lenin (Matanzas), agricultural season 2009-2010, L3A1=Locality Agricultural Enterprise La Cuba (Ciego de Ávila), L3A2=Locality Agricultural Enterprise La Cuba (Ciego de Ávila), agricultural season a 2009-2010

Figure 2. Biplot representations to total yield t ha^{-1} corresponding to 16 genotypes (axis 1 and 2) in six environments (vectors) by AMMI model

This result may indicate that the same environmental effect does not act equally on the behavior of progenies, they showed different behavior, comparable study reported by Navarro (10), who indicated that genes can not make it expresses a character if not properly and, conversely, any environmental manipulation will develop some property if not present the necessary genes.

These results could be expressing a better performance of hybrid and PL progenies than witness' genotypes, which are commercial cultivars with adaptation and stability to contrasting environments.

The results in this paper suggest the great influence of the environment and that brings the differential behavior of genotypes.

Yield is a highly variable attribute is influenced by year, location, soil type, soil fertility, technology and genotype; hence the stability of a genotype in a wide range of environments has an importance significant in selecting progenitors and commercial cultivars.

The results obtained are similar to those obtained in other studies (7), where it was reported that the Romano and Desirée varieties have been the most stable and best performing in production for several years in Cuba. They coincide with those found by other authors (11), who determined the performance contrasts tubers from TPS among different places, which is attributed to the genotype-environment interaction and suggests the need to evaluate genotypes in each production area (12).

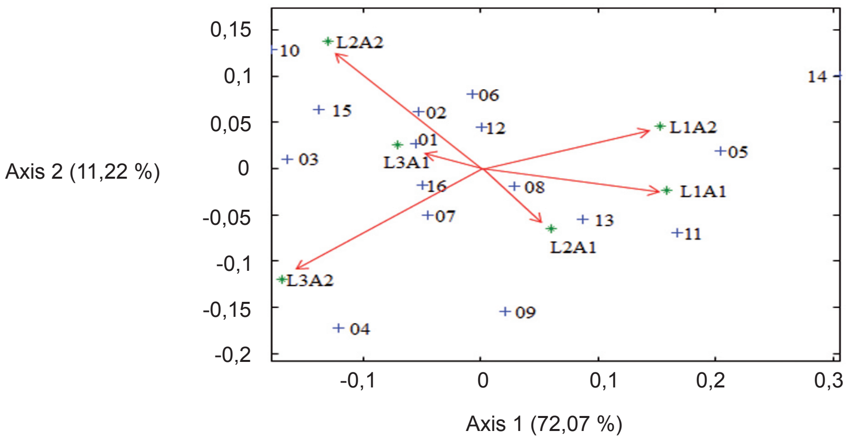
It has been reported using the model of additive main effects and multiplicative interaction (AMMI) to classify environments with higher yields of tubers, and select the most outstanding and positive correlation with two locations-two years

In this sense, some authors state, by AMMI model, potato varieties more stable for yield characters and its components in nine different places (8).

Although yields is the result of genotype effects of (G), the environment (E) and genotype-environment interaction (GE), only the main effect of G and GE interaction are of relevance in assessing genotypes (13).

Differentiation of means can identify different behaviours among genotypes, which could be used in a breeding program and select for use commercially, coinciding with recommended when the potato genotype- environment interaction was analyzed using AMMI methodology for identifying stable genotypes and adapted to specific locations (3).

In Figure 3 both axis (1 and 2) are explaining the 83,29 % of the genotype-environment interaction for average tuber mass, axis 1 explains 72,07 % of interaction, while axis 2 the remaining 11,22 %.



1=9-80-98-PL, 2=Atlantic x 6-3-98, 3=Atlantic x Aninca, 4=Cal White (T), , 5=Gorbea x 1-10-96, 6=Lajera x 6-3-98, 7=Gorbea x 6-3-98, 8=Lajera x 9-80-98, 9=Romano (T), 10=Samila x 2-130-98, 11=Samila x 6-3-98, 12=Samila-PL, 13=Spunta (T), 14=Yara x 1-10-96, 15=Yara x 9-80-98, 16=Yara-PL. L1A1=Locality INCA (Mayabeque), agricultural season 2008-2009, L1A2=Locality INCA (Mayabeque), agricultural season 2009-2010, L2A1=Locality Agricultural Enterprise V. Lenin (Matanzas), agricultural season 2008-2009, agricultural season 2008-2009, L2A2=Locality Agricultural Enterprise V. Lenin (Matanzas), agricultural season 2009-2010, L3A1=Locality Agricultural Enterprise La Cuba (Ciego de Ávila), L3A2=Locality Agricultural Enterprise La Cuba (Ciego de Ávila), agricultural season 2009-2010

Figure 3. Biplot representation to average mass (kg) corresponding to 16 genotypes (axis 1 and 2) in six environments (vectors) by AMMI model

Progenies 1 (9-80-98-PL), 7 (Gorbea x 06/03/98), 8 (Lajera x 9-80-98), 16 (Yara-PL) and 12 (Samila-PL) were the more stable for the average mass of the tuber.

Figure 3 shows that progenies 10 (2-130-98 Samila x) and 15 (Yara x 9-80-98) interacted positively in L2A2 and negatively in L1A2 and L1A1. The witness cultivar # 4 (Cal White) interacted positively in L3A2 and negatively in L1A2 and L2A2. While in L1A2 and L1A1, progenies 5 (Gorbea x 10/1/96) and 14 (Yara x 01/10/96) responded positively, but had a negative response in L3A2.

Also, recently it has established an effective method to study the stability of potato varieties in several locations and years, using a generalized AMMI model and can be represented by an interactive Biplot (8).

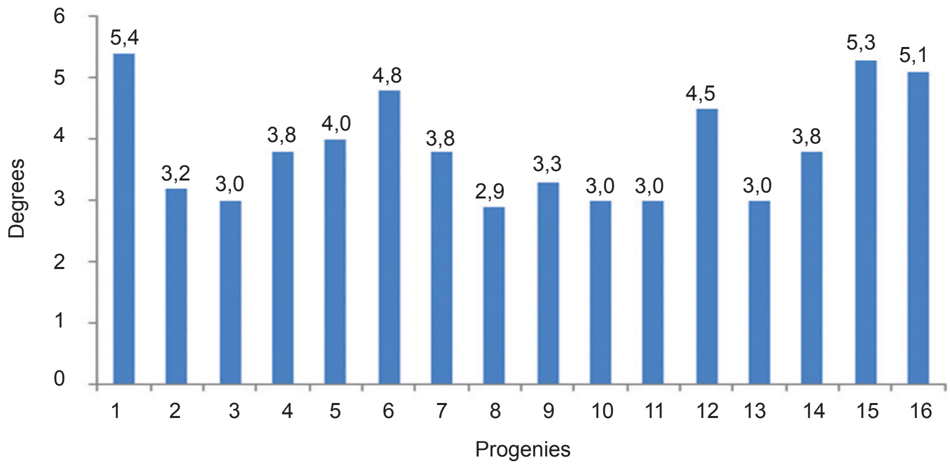
Figure 4 shows generally that hybrid progenies and witnesses varieties showed the lowest degree of involvement of *Alternaria solani*, causal agent of early blight on foliage, important disease of potato cultivation in Cuba. These results may indicate that one of the criteria used in the breeding program for variety production was the tolerance to this disease in field conditions. It occurs every year and varied aggression, probably due to climatic conditions and crop management, for which it has become a key pathology of the crop that can potentially cause significant losses, a result that corroborates determined by some authors (14), whereby this disease occurs almost every year and with varying intensity, probably due to the wide range of planting times.

Figure 4 gives a general overview of the involvement by *Alternaria solani* that causes early blight disease. Hybrid progenies as Lajera x8=9-80-98, 3=xAninca Atlantic 10=Samila 2-130-9x11=x03-06-98 Samila presented low degree of affectation, a result that could indicate that used progenitors have resistance and tolerance genes, while combining high ability to transmit it to offspring.

This figure also shows that PL progenies reached higher degree of involvement, outcomes that may be influenced by the presence of some degree of inbreeding in such genetic material.

This result could be influenced by genetic disposition of cultivars that change to a greater or lesser extent the attack of this fungus. Resistance expression also depends on the disease pressure. Under field conditions (natural) pressure can vary considerably from one year to another and then some progenies may escape susceptible to infection and erroneously pretend resistance.

This result could also be related to host-pathogen interactions, which are influenced by a genotype-environment interaction. *A. solani* infection that causes early blight may be aided by heat and drought stress, deficiency of sulfur, nitrogen and manganese or early senescence of the plant, results agree with those found when the resistance and heritability of the plant maturity were analyzed in different potato varieties (15, 16).



1=9-80-98-PL, 2=Atlantic x 6-3-98, 3=Atlantic x Aninca, 4=Cal White (T), , 5=Gorbea x 1-10-96, 6=Lajera x 6-3-98, 7=Gorbea x 6-3-98, 8=Lajera x 9-80-98, 9=Romano (T), 10=Samila x 2-130-98, 11=Samila x 6-3-98, 12=Samila-PL, 13=Spunta (T), 14=Yara x 1-10-96, 15=Yara x 9-80-98, 16=Yara-PL

Figure 4. Mean affectations in the foliage by *Alternaria solani* in six environments using a scale of 1-9 degrees

CONCLUSIONS

- The progeny 6 (Lajera x 03/06/98) is promising for potato production for its high and stable yield and tuber yield.
- Progenies 10 (Samila x 2-130-98), 14 (Yara x 1/10/96), 15 (Yara x 9-80-98), 3 (Atlantic x Aninca) and 11 (Samila x 03/06/98) were characterized by their instability in the number of tubers in the performance and average mass.

RECOMMENDATIONS

The contrasts in the agronomic performance of the progenies of sexual seed among different localities are attributed to the genotype-environment interaction, suggesting the need to assess materials in each production area.

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