Key locations for soybean genotype assessment in Central Brazil

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Abstract – The objective of this work was to identify key locations for the establishment of soybean (*Glycine max*) genetic breeding programs, in the Central Region of Brazil. Grain yield data of three maturity groups of soybean genotypes, from regional trials conducted over three years, at 18 locations in Brazilian Cerrado were used. A key location for the early phases of the breeding program was defined as the site that best classifies the winning genotypes in the region. Key locations for the final phases were defined as those sites that best represent each environmental stratum, in relation to the adaptability of the respective winning genotype. This adaptability was estimated by additive main effects and multiplicative interaction (AMMI) model analysis, using the distance between the score of each location in a stratum and the score of the winning genotype, which characterizes such stratum in an AMMI biplot. The locations that best classified the winning genotypes over space and time were Mineiros, Placas and Rio Verde. For the final phases of genotype selection, with data from the three maturity group, the recommended locations were: Buritis, Chapadão do Céu, Iraí, Pamplona, Placas, Planaltina, Rio Verde, Sacramento, Senador Canedo, Uberaba, and Uberlândia.

Index terms: *Glycine max*, adaptability, AMMI analysis, environmental stratification, G×E interaction.

Locais-chave para avaliação de genótipos de soja na Região Central do Brasil

Resumo – O objetivo deste trabalho foi identificar locais-chave para o estabelecimento de programas de melhoramento genético de soja (*Glycine max*), na Região Central do Brasil. Foram utilizados dados de produtividade de grãos de genótipos de soja, de três ciclos de maturação, obtidos de ensaios regionais conduzidos por três anos em 18 localidades da região. O local-chave para a condução das fases preliminares do programa foi definido como a localidade que melhor classifica os genótipos vencedores na região. Os locais-chave para as fases finais foram definidos como os que melhor representam cada estrato ambiental identificado, em termos da adaptabilidade do respectivo genótipo vencedor. Essa adaptabilidade foi estimada por meio do modelo de efeitos principais aditivos e interação multiplicativa (AMMI), tendo-se utilizado a distância entre os pontos (escores) correspondentes a cada local em um estrato e o escore do genótipo vencedor que caracteriza aquele estrato, em um "biplot" AMMI. Os locais que melhor classificaram os genótipos vencedores ao longo do espaço e do tempo foram: Mineiros, Placas e Rio Verde. Para as fases finais de seleção de genótipos, com os dados dos três ciclos de maturação, os locais recomendados foram: Buritis, Chapadão do Céu, Iraí, Pamplona, Placas, Planaltina, Rio Verde, Sacramento, Senador Canedo, Uberaba e Uberlândia.

Termos para indexação: *Glycine max*, adaptabilidade, análise AMMI, estratificação ambiental, interação G×E.

Introduction

Intensive management techniques for soybean (*Glycine max* L.) crop, allied to genetic breeding, have resulted in expressive increases in grain productivity. With the genetic breeding progress, research activities have become more expensive, requiring greater care and technical refinement. It is, therefore, important to critically assess genotypes as for the environments targeted by the research. Thus, in the process of developing genetic materials adapted to a region, an aspect that has drawn the attention of researchers is the genotype x environment (GE) interaction. The presence of this interaction is characterized by the alteration in

the phenotypic variance of a set of genotypes submitted to different environmental conditions, or by the lack of correlation among genotype responses in the series of environments. The occurrence of this phenomenon can lead to overestimations of the heritability value, because the GE interaction inflates the genotypic variance estimates with constant overvalue of the predicted gain with selection. It can also result in productivity reduction of a region for which a general recommendation of a given cultivar is made.

Germplasm evaluations for advancement in crop breeding programs, such as advanced soybean line experiments, are commonly carried out in several locations, under heterogeneous environmental conditions and with a large number of genotypes. Some evaluations have shown that the subdivision of production areas into megaenvironments is not justified, as reported in studies with peanuts by Casanoves et al. (2005) and Putto et al. (2008), respectively for Argentina and Thailand. Studies like those conducted by Dehghani et al. (2006) and Roozeboom et al. (2008), however, confirmed the effectiveness of the proposed subdivision for reducing GE interaction.

The production optimization in a region, where significant GE interaction has been identified, is related to the possibility that this region can be divided into relatively homogeneous zones, and that the best performing genotypes in each one can be designated to them. These homogeneous zones or subregions, also called as agroecological zones, are equivalent to a regionalization that has been more widely called megaenvironment (International Maize and Wheat Improvement Center, 1989). According to this concept, a megaenvironment consists of large areas, not necessarily continuous, usually international and frequently transcontinental, defined by being similar in terms of biotic and abiotic stress, crop system, consumer preferences etc.

Without subdivision into zones, only a cultivar of wide adaptation can be recommended, but with the environmental stratification, the specific adaptations of genotypes can also be exploited. In this sense, Gauch Junior & Zobel (1997) argued that although the stratification of a crop region may imply a greater volume of work for breeders and seed producers, it results in higher heredities and, therefore, faster genetic progress in the target area of the breeding programs. Furthermore, it leads to greater competitive capacity among the seed producers and higher yields for the farmers.

Another important aspect comes up when homogeneous locations are identified in a region, because they can be redundant for the genetic breeding program. Thus, the choice of only one of these locations for genotype testing will increase the efficiency of the program. This kind of study characterizes the definition of key locations, and consists of choosing a local representative for each homogeneous subregion identified in the environments under evaluation. Crossa (1990) and Gauch Junior & Zobel (1997) indicated AMMI analysis as a helpful statistical tool to identify highly productive and widely adapted genotypes, as well as to identify key locations to carry out selection in plant breeding programs. Other statistical analyses, based on singular value decomposition (SVD), have been proposed, such as the genotype main effects and genotype × environment interaction (GGE) model (Yan et al., 2000, 2007; Yan & Tinker, 2005). These papers describe some advantages of the GGE biplot model compared to AMMI biplot. Nevertheless, recent review articles reinforce the recommendation to use the AMMI model (Gauch Junior, 2006; Gauch Junior et al., 2008).

Brazil is the second largest world producer of soybean (exceeded only by the United States) with almost 60 million tons of this grain (IBGE, 2009). About 60% of this production comes from the Cerrado region, where about 12 million ha of soybean are grown, with an average yield of nearly 3 Mg ha^{-1} (higher than the national average – 2.8 Mg ha^{-1}). Despite this national and international importance, comprehensive studies of environmental stratification, based on GE interaction in soybean, have not yet been developed for this region.

The objective of this work was to identify key locations to carry out a soybean genetic breeding program for the Central Region of Brazil, with emphasis in the phases of preliminary line assessment and final cultivar recommendation.

Materials and Methods

Grain yield data from regional trials for soybean line assessment in three agricultural seasons (1999/2000, 2000/2001 and 2001/2002) were used. The lines of early, medium and late maturity groups (cycles) were, in part, replaced for new ones from one year to another. This is

a positive aspect for inference purposes of this study, because the soybean germplasm cropped in the target region was better represented. The complete data used were presented by Pacheco (2004). The experiments were carried out in 18 locations in the Central Region of Brazil, also called Cerrado region, in the states of Goiás, Mato Grosso, Bahia, and Minas Gerais and in the Federal District (Table 1). A randomized complete block design was used in each trial, with four replicates. The treatments consisted of test lines and cultivars of soybean, whose number ranged from 23 to 28, depending on the growing year and maturity group. The plots consisted of four 5 m rows spaced at 0.5 m, and the two central rows were considered as the useful plot area, discarding 0.5 m from each end.

To define the key locations in the trial network, the most representative ones of each stratum were sought based on the environmental clustering obtained by Pacheco (2004). The stratification performed by Pacheco (2004) was done according to the AMMI analysis of GE interaction (Zobel et al., 1988; Duarte & Vencovsky, 1999), associated to the winning genotype approach proposed by Gauch Junior (1992) and Gauch Junior & Zobel (1997). In this approach, a winning genotype was the one that attains the highest yield in a given environment. These genotypes have, therefore, the best specific adaptation to the stratum that they determine, as well as agronomic stability for the locations that make up this stratum.

The key locations for the final phases of the breeding program were defined as those that should be primarily chosen in each stratum for the genotypic assessment and selection steps, whose main purpose is to provide cultivars for the region represented by such locations. The coordinates (scores) of environments and genotypes were displayed in a graphic representation called biplot (Gabriel, 1971, 1978). These scores were estimated by AMMI analysis, specifically from setting the AMMI1 model, that is, with only one interaction axis, named IPCA1. Then, for each identified stratum, the Euclidean average distances between the graphic points related to the stratum locations and its winning genotype were obtained. The location with the lowest average distance to the winning genotype over the years was chosen preliminary as the key location for that stratum.

The indication of a key location to carry out the initial phases of the selective process (eg. generation advance) was established by ranking winning genotypes in all locations of the trial network. Thus, a key location for these phases was defined as the one that best classified the winning genotypes, over the years, i.e., the location that minimizes the probability of discarding winning genotypes in the target region. For the identification of the key location, the mean of the yield ranks of these genotypes in each location, weighted by the numbers of their wins, taking account all the locations, was used. In order to prevent the definition of a key location only for the initial phases of the selection process, this site was chosen among those previously defined as key locations to carry out the final selection phases.

Table 1. Brazilian locations and their geographic coordinates, where the variety trials of soybean test lines and cultivars were carried out in this study[1].

Location	Latitude South	Longitude West	Altitude (m)
Anápolis, GO	16º 27'	48º 57'	1,017
Chapadão do Céu, GO	18º 32'	52º 32'	800
Cristalina, GO	16º 50'	47º 36'	930
Luziânia, GO	16º 16'	47º 57'	930
Mineiros, GO	17º 34'	52º 33'	980
Rio Verde, GO	17º 41'	50º 55'	730
Senador Canedo, GO	16º 33'	49º 05'	801
Correntina, BA	13º 33'	44º 38'	950
Placas, BA	11º 08'	47º 38'	780
Pamplona, DF	16º 05'	47º 30'	1,008
Planaltina, DF	15º 31'	47º 36'	1,003
Buritis, MG	15º 27'	46º 25'	900
Capinópolis, MG	18º 41'	49º 34'	950
Conquista, MG[2]	19º 52'	47º 32'	830
Iraí de Minas, MG	18º 57'	47º 27'	975
Sacramento, MG	19º 51'	47º 26'	1,038
Uberaba, MG[3]	19º 42'	47º 55'	781
Uberlândia, MG	19º 05'	48º 16'	1,012
Lucas do Rio Verde, MT	13º 09'	55º 54'	350

[1]Latitude and longitude data were provided by Embrapa Cerrados and refer to the trial location, while altitude data were provided by IBGE (2008) and refer to the headquarters of the closest municipality.[2]Only for late maturity group.[3]Not for late maturity group.

Results and Discussion

Location for genotype tests in the final selection phases

The environmental stratification into homogeneous groups leads to the need for identification of key locations within these groups, where the genotype tests should be prioritized in the selection phases of the plant breeding programs.

The strata and the distances (d^2_{vj}) between each location (j) and the winning genotype (v) within each stratum and growing year are shown in Tables 2, 3, and 4

(early, medium and late maturity groups, respectively). These tables also show the means of these distances in the three growing years ($\overline{d}^2_{vj}$), for each test location. Examination of these results allows the identification of the key location, for the final phases of the genotypic assessment related to the target populations of the genotypes and environments.

The results for the early maturity group (Table 2) show that in the first three environmental clusters obtained, Buritis, Luziânia, and Pamplona were the locations that most geometrically approached the winning genotype that characterized their respective strata. It was further observed that in growing year 2000, Buritis was the third location closest to the winning genotype in the first cluster, and showed a small distance to this genotype in 2001, as well as the second shortest distance in 2002. In the second cluster, Luziânia was the closest location to the respective winning genotype, in 2000 and 2002, and was ranked as third (very close to the second) in 2001. In the other cluster, Pamplona was geometrically the nearest from the winning genotypes in 2000 and 2001, and was ranked as the second closest location in 2002. Based on these results, eight key locations were chosen for the final stages of early maturity group genotype assessment: Buritis, Luziânia, and Pamplona, reported previously, and Iraí, Chapadão do Céu, Uberaba, Planaltina, and Senador Canedo, that should also be indicated because they did not group with other locations.

For the medium maturity group genotypes (Table 3), also in the first three environmental clusters obtained, it was observed that the locations Buritis, Anápolis, and Pamplona showed the smallest mean Euclidean distances, in relation to the winning genotypes that characterized each of these clusters. It was further verified that, in the growing year 2000, these locations were ranked at second place regarding their distances to the respective winner genotype, and were basically the closest in the other years, except for Anápolis, in 2001, that was also in second place, but very close to

Table 2. Environmental strata and winning genotypes with their GE interaction scores (IPCA1), estimated by AMMI analysis, and the quadratic distances (D^2) between each location and the winning genotype of the respective stratum, for the early maturity group of soybean genotypes, in three assessment years[(1)].

Environmental strata	2000		2001		2002		$\overline{D}^{2\,(2)}$
	IPCA1	D^2	IPCA1	D^2	IPCA1	D^2	
Buritis, MG	-5.68	31.69	-7.38	0.05	-13.53	5.06	12.27
Lucas do Rio Verde, MT	-9.73	93.69	1.15	74.64	-15.97	0.04	56.82
Capinópolis, MG	8.43	71.92	-14.98	54.32	-6.58	84.64	70.29
Rio Verde, GO	-3.14	9.55	2.79	108.16	-6.11	93.51	70.40
Correntina, BA	-2.37	5.38	-15.56	63.20	-27.80	144.48	71.02
Winning genotypes	BR89-10744 CE; IPCA1 = -0.05		MG/BR95-964; IPCA1 = -7.61		Apiakas; IPCA1 = -15.78		
Luziânia, GO	0.48	0.28	3.38	120.78	10.96	1.85	40.97
Placas, BA	-6.14	37.08	3.31	119.25	4.37	27.35	61.23
Mineiros, GO	-5.71	32.03	4.68	151.04	7.76	3.39	62.15
Cristalina, GO	5.55	31.36	-4.46	9.92	-4.13	188.51	76.60
Sacramento, MG	6.38	41.35	8.07	245.86	13.42	14.59	100.60
Winning genotypes	BR89-10744 CE; IPCA1 = -0.05		MG/BR95-964; IPCA1 = -7.61		MGBR97-2545; IPCA1 = 9.60		
Pamplona, DF	10.66	23.08	-0.01	57.76	4.81	22.94	34.59
Anápolis, GO	16.07	104.33	6.20	190.72	7.97	2.66	99.23
Uberlândia, MG	13.47	57.97	3.63	126.34	30.16	422.71	203.34
Winning genotypes	BR95-15305 CE; IPCA1 = 5.86		MG/BR95-964; IPCA1 = -7.61		MGBR97-2545; IPCA1 = 9.60		
Iraí de Minas, MG	-21.12	-	30.95	-	30.90	-	-
Winning genotypes	BR96-019431 MG		BRAS97-8091		MGBR97-2545		
Chapadão do Céu, GO	-9.61	-	11.58	-	-9.05	-	-
Winning genotypes	BR89-10744 CE		BRAS97-8091		Apiakas		
Uberaba, MG	-21.00	-	-0.04	-	-7.86	-	-
Winning genotypes	BR96-019431 MG		MGBR95-964		GOBR96-014101		
Planaltina, GO	26.07	-	-2.17	-	-24.17	-	-
Winning genotypes	G: BR95-7783 CE		G: MGBR95-964		Apiakas		
Senador Canedo, GO	-2.61	-	-30.78	-	4.86	-	-
Winning genotypes	BR89-10744 CE		FT-2000		MGBR97-2545		

[(1)]Environment stratification was performed by Pacheco (2004), according to AMMI analysis of GE interaction (Zobel et al., 1988; Duarte & Vencovsky, 1999), associated to the winning genotype approach proposed by Gauch Junior (1992) and Gauch Junior & Zobel (1997). [(2)]$\overline{D}^2$ is the mean quadratic distance through the years.

Sacramento, that showed the smallest mean distance to the respective winning genotype. In addition, it was verified that the locations closer to the winning genotype in 2000, Planaltina, Capinópolis, and Mineiros, in these three clusters, were fairly apart from this genotype kind in the following years, so they should not be indicated. The same fact occurred with Sacramento location, in the years in which it was not the geometrically closest location to the winning genotype (2000 and 2002). Thus, for the final assessment phases of the medium maturity group genotypes, six locations were chosen: Buritis, Anápolis, and Pamplona, reported previously, and Iraí, Chapadão do Céu, and Uberlândia, which did not group to other locations and showed to be environments with peculiar characteristics in the target region.

For the late maturity group (Table 4), in the first four environmental clusters identified, the IPCA1 scores of the locations Rio Verde, Buritis, Placas, and Pamplona showed the smallest mean distances in relation to the respective winning genotypes. Although Rio Verde was not the location geometrically closest to the winning genotype in any of the years, this site maintained a small distance in relation to the winners in the three years considered, and was , therefore, chosen. The locations that were the closest to the winning genotype in this cluster, in each year (Senador Canedo in 2000, and Mineiros in 2001 and 2002), showed great distancing at least in one year, increasing the mean distances related to the winning genotype. In the second cluster, with only two locations, Buritis was the closest one to the winners in two years (2000 and 2002); and in the third cluster, Placas was also the closest location to the respective winning genotype in two years (2000 and 2001). In the last cluster, also composed by only two locations, Pamplona was practically tied with Planaltina, in 2000, and geometrically much closer to the winner in 2001. Thus, for the final assessment phases of the late maturity group genotypes, seven key locations were chosen: Rio Verde, Buritis, Placas, and Pamplona, plus the locations Sacramento, Iraí, and Uberaba, because they did not group to other locations.

Finally, attempts were made to identify, among the key locations chosen for each maturity group, those

Table 3. Environmental strata and winning genotypes with their GE interaction scores (IPCA1), estimated by AMMI analysis, and the quadratic distances (D^2) between each location and the winning genotype of the respective stratum, for the medium maturity group of soybean genotypes, in three assessment years[(1)].

Environmental strata	2000		2001		2002		$\overline{D}^{2}$ [(2)]
	IPCA1	D^2	IPCA1	D^2	IPCA1	D^2	
Buritis, MG	-17.11	13.81	26.72	12.82	-9.95	2.92	9.85
Cristalina, GO	-5.78	57.98	14.95	67.08	-3.06	26.83	50.63
Correntina, BA	-7.65	33.00	30.22	50.13	-18.69	109.20	64.11
Planaltina, DF	-11.6	3.22	11.56	134.10	-16.32	65.29	67.53
Placas, BA	-3.12	105.56	2.24	436.81	-0.40	61.47	201.28
Rio Verde, GO	7.17	422.56	0.64	506.25	-2.47	33.29	320.81
Uberaba, MG	1.19	212.70	-7.01	909.02	-21.26	169.52	430.41
Lucas do Rio Verde, MT	2.13	241.00	-8.77	1018.25	-16.51	68.39	442.55
Winning genotypes	BR92-2658 CE; IPCA1 = -13.39		BRAS97-0009; IPCA1 = 23.14		MSOY-8411; IPCA1 = -8.24		-
Anápolis, GO	-7.75	31.86	-22.81	7.29	9.49	3.17	14.11
Senador Canedo, GO	-2.72	113.94	-13.86	147.62	6.72	20.70	94.09
Capinópolis, MG	-9.94	11.93	-11.89	185.50	-2.55	190.99	129.48
Sacramento, MG	0.94	205.47	-22.98	6.40	-2.26	183.06	131.64
Winning genotypes	BR92-2658 CE; IPCA1 = -13.39		BR97-09894; IPCA1 = -25.51		BRA97-6705; IPCA1 = 11.27		-
Pamplona, DF	-4.42	80.54	10.09	170.30	11.97	0.49	83.78
Luziânia, GO	-1.67	137.46	6.34	282.24	15.07	14.44	144.71
Mineiros, GO	-7.94	29.75	-4.83	782.32	5.30	35.64	282.57
Winning genotypes	BR92-2658 CE; IPCA1 = -13.39		BRAS97-0009; IPCA1 = 23.14		BRA97-6705; IPCA1 = 11.27		-
Iraí de Minas, MG	50.57	-	-22.25	-	19.93	-	-
Winning genotypes	BR96-016119		BR97-09894		GOBR97-11587		-
Chapadão do Céu, GO	26.44	-	23.53	-	-11.69	-	-
Winning genotypes	BR96-013721		BRAS97-0009		MSOY-8411		-
Uberlândia, MG	7.99	-	-12.39	-	36.68	-	-
Winning genotypes	BR96-013721		Conquista		GOBR97-11587		-

[(1)]Environment stratification was performed by Pacheco (2004), according to AMMI analysis of GE interaction (Zobel et al., 1988; Duarte & Vencovsky, 1999), associated to the winning genotype approach proposed by Gauch Junior (1992) and Gauch Junior & Zobel (1997). [(2)]$\overline{D}^{2}$ is the mean quadratic distance through the years.

that might represent the three cycles simultaneously. It was further possible to remove two sites of the 13 key locations initially chosen throughout the region, Anápolis (medium maturity cycle) and Luziânia (early maturity cycle), that could be represented, respectively, by Senador Canedo (second smallest mean distance in its stratum, in the medium maturity group) and Placas (second smallest mean distance in its stratum, in the early maturity group). As these two locations were already part of the previous list of key locations, the total number of test points chosen as priority for the final selection phases in the breeding program could be reduced from 18 to 11 locations: Buritis, Pamplona, Placas, Rio Verde, Senador Canedo, Chapadão do Céu, Iraí, Uberlândia, Uberaba, Planaltina, and Sacramento.

The results obtained in this study suggest that future soybean genotype trials could be cost-effectively conducted in a few representative sites selected from within each of the identified site groups. Recently, other papers have shown similar opportunity to different crops in different parts of the world, like Dehghani et al. (2009) with corn in Iran, Sanii et al. (2009) with rice in Africa, and Miranda et al. (2009) with popcorn in Brazil.

Locations for genotype tests in the initial phases of selection

The results shown in Tables 5, 6, 7, and 8 provide information related to the choosing of a key location for initial phases of the breeding program under study.

The winning genotypes with early maturity cycle were best classified in Rio Verde, Placas, and Cristalina (Table 5), which made these locations as putative key locations for the initial phases of selection. For the medium maturity winning genotypes, the outstanding locations were Mineiros, Placas, and Rio Verde (Table 6), which were also candidate key locations for initial phases. For the late maturity group (Table 7), the locations Chapadão do Céu, Mineiros, and Anápolis were identified as the ones that best classified the winning genotypes.

It was further observed that the genotypes with greater numbers of victories in the set of assessed

Table 4. Environmental strata and winning genotypes with their GE interaction scores (IPCA1), estimated by AMMI analysis, and the quadratic distances (D^2) between each location and the winning genotype of the respective stratum, for the late maturity group of soybean genotypes, in three assessment years(1).

Environmental strata	2000		2001		2002		$\overline{D}^{2}$ (2)
	IPCA1	D^2	IPCA1	D^2	IPCA1	D^2	
Rio Verde, GO	-5.22	24.50	1.68	7.73	0.69	5.34	12.52
Capinópolis, MG	-3.10	49.98	1.31	9.92	-3.47	3.42	21.11
Anápolis, GO	-5.04	26.32	8.41	15.60	7.25	31.70	24.54
Mineiros, GO	0.68	117.72	4.67	0.04	-1.70	0.01	39.26
Senador Canedo, GO	-8.09	4.33	13.10	74.65	-9.92	68.89	49.29
Lucas do Rio Verde, MT	5.04	231.34	1.54	8.53	-4.51	8.35	82.74
Chapadão do Céu, GO	3.76	194.04	12.33	61.94	-11.04	88.74	114.91
Conquista, MG	-3.05	50.69	16.43	143.28	12.30	193.77	129.25
Winning genotypes	BR96-11552 CE; IPCA1 = -10.17		GOBR95-12203; IPCA1 = 4.46		BR97-11548; IPCA1 = -1.62		-
Buritis, MG	11.96	76.75	-26.32	256.00	0.37	3.96	45.31
Luziânia, GO	5.87	220.55	-5.48	23.43	9.73	128.82	92.42
Winning genotypes	MSOY-8800 (T); IPCA1 = 20.72		Uirapuru; IPCA1 = -10.32		BR97-11548; IPCA1 = -1.62		-
Placas, BA	-9.03	1.30	-3.03	53.14	5.75	54.32	36.25
Cristalina, GO	-6.44	13.91	-23.35	169.78	-2.87	1.56	61.75
Correntina, BA	-27.55	302.06	-20.29	99.40	2.62	17.98	139.81
Winning genotypes	BR96-11552 CE; IPCA1 = -10.17		Uirapuru; IPCA1 = -10.32		BR97-11548; IPCA1 = -1.62		-
Pamplona, DF	-3.58	43.43	-4.11	38.56	-21.05	53.93	45.31
Planaltina, GO	-3.71	41.73	-25.18	220.82	-24.56	17.70	92.42
Winning genotypes	BR96-11552 CE; IPCA1 = -10.17		Uirapuru; IPCA1 = -10.32		BR95-28822; IPCA1 = -28.39		-
Iraí de Minas, MG	40.88	-	17.06	-	18.69	-	-
Winning genotypes	MGBR95-20937		MGBR97-2762		GOBR97-08728		-
Sacramento, MG	10.13	-	19.59	-	-0.08	-	-
Winning genotypes	MSOY-8800 (T)		GOBR97-061004		BR97-11548		-
Uberaba, MG	-3.45	-	11.65	-	36.29	-	-
Winning genotypes	BR96-11553 CE		GOBR95-12203		GOBR97-08728		-

(1)Environment stratification was performed by Pacheco (2004), according to AMMI analysis of GE interaction (Zobel et al., 1988; Duarte & Vencovsky, 1999), associated to the winning genotype approach proposed by Gauch Junior (1992) and Gauch Junior & Zobel (1997). (2)$\overline{D}^{2}$ is the mean quadratic distance through the years.

locations were, frequently, identified as promising genotypes in the locations defined here as putative key locations. For the early maturity group, among the genotypes with greater numbers of victories in each year, only MGBR97-2545 genotype, in 2002, was not a winner in one of the candidate locations (Rio Verde), where, however, it was placed second (Table 5). For the medium maturity group, only 'MSOY-8411', also in 2002, was not the winner in one of the candidate locations (Mineiros), but was placed third (Table 6).

Table 5. Ranks of the grain yield means for the soybean winning genotypes of the early maturity group, in each location[(1)].

Winning genotypes	Number of wins	Rver	Plac	Cris	Pamp	Lrve	Buri	Ubba	Luzi	Mine	Capi	Scan	Cceu	Anap	Sacr	Ubrl	Corr	Plan	Iraí
										2000									
BR95-15305 CE	4	2	2	2	1	2	2	6	2	2	1	2	2	3	1	1	2	4	6
BR95-7783 CE	2	20	23	7	5	26	22	26	14	22	6	18	26	1	7	3	18	1	26
BR89-10744 CE	10	1	1	1	3	1	1	2	1	1	2	1	1	4	2	4	1	7	2
BR96-019431 CE	2	7	4	15	22	3	4	1	10	4	20	7	3	23	16	23	7	24	1
Year average		4.00	4.00	3.44	4.89	4.22	3.89	5.44	3.67	3.89	4.22	3.78	4.22	5.56	3.89	5.33	3.78	7.56	5.44
Rank in the year		9	8	1	13	12	5	16	2	6	10	4	11	17	7	14	3	18	15
										2001									
MG/BR95-964	10	1	1	1	1	1	1	1	1	2	2	2	6	3	4	1	2	1	14
BR97-09853	2	2	2	5	3	2	6	3	2	1	10	14	2	1	2	2	10	3	7
BRAS 97-8091	3	5	5	18	12	9	22	12	5	5	23	25	1	2	1	5	23	15	1
FT-2000	3	10	11	3	6	6	2	6	11	14	1	1	18	17	17	11	1	5	23
Year average		3.28	3.44	4.61	3.89	3.28	5.22	3.89	3.44	4.39	6.22	7.00	6.72	4.94	5.44	3.44	6.22	4.22	12.56
Rank in the year		1	4	10	6	2	12	7	3	9	15	17	16	11	13	5	14	8	18
										2002									
MGBR97-2545	10	2	1	1	1	5	3	3	1	1	2	1	3	1	1	1	9	9	1
GOBR96-014101	3	1	2	2	2	2	2	1	2	2	1	2	2	2	2	5	6	5	5
APIAKAS	5	3	4	3	4	1	1	2	14	10	3	4	1	10	15	17	1	1	17
Year average		2.11	2.00	1.72	2.00	3.39	2.28	2.39	4.78	3.67	2.11	2.00	2.28	3.67	5.06	6.11	6.28	6.11	6.11
Rank in the year		5	2	1	3	10	7	9	13	11	6	4	8	12	14	15	18	16	17
										General average									
		3.13	3.15	3.26	3.59	3.63	3.80	3.91	3.96	3.98	4.19	4.26	4.41	4.72	4.80	4.96	5.43	5.96	8.04
Final rank		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

[(1)]The locations are identified as: Rio Verde (Rver), Placas (Plac), Cristalina (Cris), Pamplona (Pamp), Lucas do Rio Verde (Lrve), Buritis (Buri), Uberaba (Ubba), Luziânia (Luzi), Mineiros (Mine), Capinópolis (MG), Senador Canedo (Scan), Chapadão do Céu (Cceu), Anápolis (Anap), Sacramento (Sacr), Uberlândia (Ubrl), Correntina (Corr), Planaltina (Plan), and Iraí de Minas (Iraí).

Table 6. Ranks of the grain yield means for the soybean winning genotypes of the medium maturity group, in each location[(1)].

Winning genotypes	Number of wins	Mine	Plac	Rver	Pamp	Ubba	Capi	Scan	Lrve	Cris	Luzi	Buri	Plan	Corr	Sacr	Anap	Ubrl	Cceu	Iraí
										2000									
BR96-013721 MG	2	20	9	20	20	7	20	8	3	17	7	24	23	20	6	20	1	1	2
BRAS95-30005 CE	3	4	3	4	4	1	4	3	1	3	3	6	4	4	1	4	2	5	5
BR96-016119 MG	1	26	26	26	26	26	26	26	21	26	26	26	26	26	25	26	6	2	1
BR92-2658 CE	12	1	1	1	1	3	1	1	6	1	1	1	1	1	3	1	8	19	21
Year average		5.00	3.61	5.00	5.00	4.39	5.00	3.50	5.67	4.50	3.39	5.78	5.33	5.00	4.22	5.00	6.11	13.72	15.11
Rank in the year		7	3	8	11	5	9	2	14	6	1	15	13	12	4	10	16	17	18
										2001									
CONQUISTA	5	2	8	6	2	1	1	1	1	15	12	15	13	15	2	2	1	15	2
BR97-09894	3	15	20	20	15	9	2	2	5	27	21	28	26	28	1	1	2	28	1
BRAS97-0009	10	1	1	1	1	3	11	14	7	1	1	1	1	1	25	25	13	1	25
Year average		3.61	6.11	5.56	3.61	3.44	6.72	8.39	5.00	9.22	7.39	9.39	8.50	9.39	14.61	14.61	7.83	9.39	14.61
Rank in the year		2	6	5	3	1	7	10	4	12	8	13	11	14	16	17	9	15	18
										2002									
GOBR97-15587	2	4	7	14	2	22	14	3	21	14	2	18	21	21	14	3	1	19	1
BRA97-6705	5	1	2	2	1	12	2	1	10	2	1	6	10	10	2	1	3	7	2
MSOY-8411	11	3	1	1	8	1	1	5	1	1	10	1	1	1	1	6	15	1	10
Year average		2.56	1.94	2.72	5.39	6.39	2.72	3.67	5.72	2.72	6.61	4.28	5.72	5.72	2.72	4.28	10.11	4.67	6.78
Rank in the year		2	1	3	11	15	4	7	12	5	16	8	13	14	6	9	18	10	17
										General average									
		3.72	3.89	4.43	4.67	4.74	4.81	5.19	5.46	5.48	5.80	6.48	6.52	6.70	7.19	7.96	8.02	9.26	12.17
Final rank		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

[(1)]Locations are identified as: Mineiros (Mine), Placas (Plac), Rio Verde (Rver), Pamplona (Pamp), Uberaba (Ubba), Capinópolis (Capi), Senador Canedo (Scan), Lucas Do Rio Verde (Lrve), Cristalina (Cris), Luziânia (Luzi), Buritis (Buri), Planaltina (Plan), Correntina (Corr), Sacramento (Sacr), Anápolis (Anap), Uberlândia (Ubrl), Chapadão do Céu (Cceu), and Iraí de Minas (Iraí).

Table 7. Ranks of the grain yield means for the soybean winning genotypes of the late maturity group, in each location[(1)].

Winning genotypes	Number of wins	Cceu	Mine	Anap	Capi	Lrve	Rver	Scan	Luzi	Conq	Plac	Sacr	Pamp	Ubba	Cris	Buri	Plan	Corr
								2000										
BR96-11552 CE	11	2	1	1	1	2	1	1	3	1	1	5	1	1	1	5	1	2
BR95-1985 CE	1	7	5	3	4	9	3	2	9	4	2	14	3	3	2	15	3	1
MSOY-8800 (T)	5	1	2	4	3	1	4	7	1	3	7	1	4	4	6	1	4	21
MGBR95-20937MG	1	4	6	12	11	3	12	20	2	11	22	2	12	12	15	2	12	25
Year average		2.11	1.78	2.56	2.28	2.17	2.56	3.78	2.72	2.28	3.89	4.22	2.56	2.56	3.22	4.28	2.56	8.50
Rank in the year		2	1	6	4	3	9	13	11	5	14	15	7	10	12	16	8	17
								2001										
GOBR95-12203	8	1	1	1	1	1	1	1	2	2	2	4	2	1	13	13	13	12
MGBR97-2762	2	3	8	4	12	12	12	3	21	1	20	2	21	4	23	23	23	23
GOBR97-061004	1	5	23	12	24	24	24	5	26	4	25	1	26	6	26	26	26	26
UIRAPURU	7	8	4	6	3	3	3	8	1	11	1	11	1	7	1	1	1	1
Year average		4.17	4.17	3.89	4.28	4.28	4.28	4.17	5.06	5.50	4.89	6.33	5.06	3.94	10.17	10.17	10.17	9.72
Rank in the year		4	3	1	6	7	8	5	10	12	9	13	11	2	15	16	17	14
								2002										
GOBR97-08728	3	12	9	11	9	11	5	12	3	1	3	8	14	1	9	6	14	4
BR97-11548	13	1	1	1	1	1	1	1	1	2	1	1	7	10	1	1	7	1
BR95-28822	2	3	12	7	10	9	19	6	22	23	21	16	1	23	12	17	1	19
Year average		3.06	3.56	3.33	3.33	3.56	3.67	3.39	3.67	4.17	3.56	3.83	7.50	9.94	3.56	3.61	7.50	3.50
Rank in the year		1	8	3	2	6	11	4	12	14	7	13	15	17	9	10	16	5
								General average										
		3.11	3.17	3.26	3.30	3.33	3.50	3.78	3.81	3.98	4.11	4.80	5.04	5.48	5.65	6.02	6.74	7.24
Final rank		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

[(1)]Locations are identified as: Chapadão do Céu (Cceu), Mineiros (Mine), Anápolis (Anap), Capinópolis (Capi), Lucas Do Rio Verde (Lrve), Rio Verde (Rver), Senador Canedo (Scan), Luziânia (Luzi), Conquista (Conq), Placas (Plac), Sacramento (Sacr), Pamplona (Pamp), Uberaba (Ubba), Cristalina (Cris), Buritis (Buri), Planaltina (Plan), and Correntina (Corr).

Table 8. Rank of the locations assessed, concerning their average capacity for highlight soybean winner genotypes, in the three maturity groups.

Location	Maturity cycle			Mean
	Early	Medium	Late	
Rio Verde, GO	1	3	6	3.3
Mineiros, GO	9	1	2	4.0
Placas, BA	2	2	10	4.7
Lucas do Rio Verde, MT	5	8	5	6.0
Capinópolis, MG	10	6	4	6.7
Pamplona, DF	4	4	12	6.7
Uberaba, MG	7	5	13	8.3
Senador Canedo, GO	11	7	7	8.3
Cristalina, GO	3	9	14	8.7
Luziânia, GO	8	10	8	8.7
Chapadão do Céu, GO	12	17	1	10.0
Conquista, MG	-	-	10	10.0
Anápolis, GO	13	15	3	10.3
Buritis, MG	6	11	15	10.7
Sacramento, MG	14	14	11	13.0
Planaltina, DF	17	12	16	15.0
Correntina, BA	16	13	17	15.3
Uberlândia, MG	15	16	-	15.5
Iraí de Minas, MG	18	18	18	18.0

For the late maturity group, only BR96-1152 did not win in Chapadão do Céu, in 2000, where it was placed second (Table 7). These results show the capacity of the chosen locations to preserve by selection most of the winning genotypes.

A general classification for the three maturity groups, covering the three years of the study, is shown in Table 8. It was verified that the locations Rio Verde, Mineiros, and Placas were the ones that ranked better (with lowest classification means) the winning genotype, taking into account the three cycles. It is interesting to observe that locations which ranked badly the winning genotypes in one cycle did also, generally, the same in the others (Sacramento, Planaltina, Correntina, Uberlândia, and Iraí). This tendency was also shown in those locations that ranked well the winning genotypes, such as Rio Verde, Mineiros and Placas. Among these, Mineiros location would be discarded according to the established criteria, because it was not elected as a key location for final assessment phases. Thus, the recommendation for developing the initial phases of the breeding program as headquarters would be Rio Verde or Placas. The option for one or another should consider additional criteria, such as administrative or operational facilities, which are relevant for the efficacy of breeding programs.

Finally, the method explained here to indicate key locations for the initial phases of selection has flexibility to indicate the location that best classifies a greater number of winners, instead of the location that best classifies the main winning genotype (first place in each location)

Conclusions

1. It is possible to reduce the trial network assessed in this study from 18 to 11 key locations: Buritis, Chapadão do Céu, Iraí, Pamplona, Placas, Planaltina, Rio Verde, Sacramento, Senador Canedo, Uberaba, and Uberlândia.

2. Rio Verde or Placas should be indicated as location for developing the initial phases of the line selection process, in the present breeding program.

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