Stability in cassava (*Manihot esculenta* Crantz) cultivar yield in *Paraná* State

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ABSTRACT. The present study was carried out to quantify the genotype x environment interaction of nine cassava cultivars and to estimate the phenotypic stability parameter by Plaisted and Peterson (1959) and Kang (1988) methodologies, in the cities of *Maringá* and *Rolândia*, located in the state of *Paraná*, southern Brazil, during the agricultural years of 1995/96, 1996/97 and 1997/98. The treatments were in complete, randomized blocks, with four replications. The Plaisted and Peterson method showed the IAC 169-86, IAC 47-86 and *Branca de Santa Catarina* cultivars to be the most stable. The IAC 169-86 and IAC 47-86 cultivars presented the lower ranks total, and therefore were considered the most stable and productive by Kang method (1988). The IAC 169-86 cultivar was a stable and productive material, resistant to bacteriosis, with average susceptibility to overlengthening, being, thus, eligible for recommendation to cassava producers in northern and northwestern *Paraná*.

Key words: cultivars, cassava, genotype x environment interaction.

RESUMO. Estabilidade de produção de cultivares de mandioca (*Manihot* esculenta, Crantz) no Estado do Paraná. Com o objetivo de quantificar a interação genótipos por ambientes de nove cultivares de mandioca e de estimar parâmetros de estabilidade fenotípica, foi desenvolvido o presente trabalho, utilizando-se as metodologias de Plaisted e Peterson (1959) e de Kang (1988), nos municípios de Maringá e Rolândia, nos anos agrícolas de 1995/96, 1996/97 e 1997/98. Os tratamentos foram delineados em blocos completos, casualizados, com quatro repetições. O método de Plaisted e Peterson (1959) mostrou as cultivares IAC 169-86, IAC 47-86 e Branca de Santa Catarina como sendo as mais estáveis. As cultivares IAC 169-86 e IAC 47-86 apresentaram a menor soma de *ranks*, sendo, portanto, consideradas as mais estáveis e produtivas pelo método de Kang (1988). A cultivar IAC 169-86 mostrou ser um material estável e produtivo, com resistência à bacteriose e susceptibilidade mediana ao superalongamento, sendo, portanto, promissora para a recomendação a mandiocultores das regiões Norte e Noroeste do Estado do Paraná.

Palavras-chave: cultivares, mandioca, interação genótipo x ambiente.

Introduction

The assessment and selection of cultivars with high yield and stability is very important in any genetic breeding program, to indicate superior materials for commercial use (Carneiro, 1998).

The inconstant performance of cultivars, when assessed in different environments, has drawn the attention from plant breeders, because the interactions among genotypes and environments can interfere negatively in the cultivar selection process (Barriga, 1980).

The genotype x environment interaction, which is the alteration in the genotype performance because of environmental differences, according to Borém (1998), indicates that the cultivars being studied are not stable, behaving differently in different environments. According to Ramalho *et al*. (1993), there are at least three options to reduce the effect of genotype x environment interaction: to identify specific cultivars for each type of environment, to carry out ecological zoning and to identify more stable cultivars with more stable phenotype. The first option to reduce the effects of interaction is theoretically, but not practically, possible. In this case, the genetic materials are assessed in several environments and the cultivars are identified by data analysis for each specific environment. The environment can become restricted by any unpredicted variation in these conditions, causing genetic materials unfitness. Furthermore, it is a very expensive solution for researching institutions, requiring a previous training to develop farming awareness, which prevents its adoption.

In the environment zoning, ecologically similar environments are grouped in sub-regions where the interaction becomes insignificant. This grouping, however, is only possible based on macro-environmental differences, which makes zoning vulnerable to unpredictable variations that may occur in any environment (Horner and Frey, 1957).

The alternative that has been most widely used is the identification of cultivars with greater phenotypic stability, abler to be applied in the most varied situations. This option requires studies on the genotypic performance based on adaptability and stability parameters, which enables identification of cultivars with predictable behavior and responsive to environmental variations, under specific or general conditions (Cruz and Regazzi, 1997).

The adaptability of a cultivar is its capacity to make good use of the environmental variations. Performance stability is related to the capacity of the materials for highly predictable behavior related to environmental variation. Adaptability and stability are characteristics of the cultivar and allow it to respond to the environment limiting factors and use the favorable factors (Borém, 1998).

There are a few studies on genetic breeding involving cassava cultivars in *Paraná*. Vigidal Filho *et al*. (2000) assessed nine cassava cultivars in the *Araruna,* state of *Paraná,* region and concluded that the *Fécula Branca* cultivar was superior because it presented good tuberous root yield and was resistant to bacteriosis, being recommended for cultivation in northwestern *Paraná*.

Rimoldi (2000) studied the adaptability and stability of cassava cultivars in the northern and northwestern regions of *Paraná*. He concluded that the IAC 45-85 cultivar was stable by the Plaisted and Peterson (1959) and Kang (1988) methods, highly resistant to bacteriosis, with average susceptibility to overlengthening, and also produced high yield in the assessed environments.

The objective of the present study was to study the genotype x environment interaction and to assess the genotypic performance of nine cassava cultivars, to verify which one(s) could better meet the needs of the cassava agroindustrial sector in the northern and northwestern *Paraná*.

Material and methods

The experiments were set up in the agricultural years 1995/96, 1996/97 and 1997/98 in the cities of *Maringá* (*Fazenda Experimental Iguatemi - UEM*) and *Rolândia* (*Cooperativa Agricultural de Rolândia - Corol*), respectively located in the northwestern and northern regions of the state of *Paraná*.

The predominant soil type in the *Maringá* experimental area is dystrophic Red Latosoil, while dystroferric Red Nitosoil predominates in the *Rolândia* experimental area (Embrapa, 1999).

The chemical analysis of the soil material sample from *Maringá* experimental area showed the following: pH (H_2O): 6,3; pH ($CaCl_2$): 5,8; $H^+ + Al^{+3}$: 2,95cmol$_c$ dm^{-3}; Al^{+3}: 0,00cmol$_c$ dm^{-3}; $Ca^{+2}+Mg^{+2}$: 5,46cmol$_c$ dm^{-3}; Ca^{+2}: 3,76cmol$_c$ dm^{-3}; K^+: 0,46cmol$_c$ dm^{-3} and P: 7,00mg dm^{-3} *Rolândia* experimental area chemical analysis showed the following: pH (H_2O): 6,20; pH ($CaCl_2$): 5,50; $H^+ + Al^{+3}$: 4,28cmol$_c$ dm^{-3}; Al^{+3}: 0,00cmol$_c$ dm^{-3}; $Ca^{+2}+Mg^{+2}$: 7,88cmol$_c$ dm^{-3}; Ca^{+2}: 6,03cmol$_c$ dm^{-3}; K^+: 1,41cmol$_c$ dm^{-3} e P: 3,80mg dm^{-3}.

The climate is CW'a in *Maringá* experimental area, that is, wet mesothermic, with summer rains and hot summer and autumn, while in *Rolândia* experimental area the climate is Cfa type, that is, dry winter with occasional night frosts, according to the Köppen classification (Godoy *et al*., 1976).

Six remaining cultivars from the last selection cycle selected by Lorenzi *et al*. (1996) in *Campinas,* state of *São Paulo*, called IAC 47-86, IAC 109-86, IAC 144-86, IAC 169-86, IAC 183-86 and IAC 187-86 were assessed in *Maringá* and *Rolândia*, in 1996/97 and 1997/98 using *Branca de Santa Catarina*, IAC 12 and Fibra cultivars as controls.

In the experiments carried out in *Maringá*, the experimental plots had 4.0m x 8.0m, with four plant rows with 1.0m between-row spacing and 0.80m between plants. The plot's useful area consisted of the two central rows, eliminating 0.80m from the ends, making a total of 12.80m^2 with 16 plants.

In *Rolândia* experimental area, the plots measured 4.80m x 8.0m, with four plant rows, spaced at 1.20m between rows and 0.80m between plants. The plot's useful area consisted of the two central rows, removing the 0.80m from the ends, totaling 15.36m^2 with 16 plants.

The experiments were set up in the first 15 days of October, by placing the manivas horizontally in drills approximately 0.10m deep and covering them with soil. Normal crop management practices were used according to Dias and Lorenzi (1992).

No fertilizer of any type was applied to give greater similarity with cassava producer reality in the regions where the experiments were set up.

The treatments were in complete, randomized blocks, with four replications, making a total of 32 experimental units in each experimental assessment.

The following characteristics were assessed: a) bacteriosis incidence (*Xanthomonas axonopodis* pv. *manihotis*, Dye *et al*., 1980) at three, six and nine months, at field level, using the scale proposed by Fukuda *et al*. (1984); b) incidence of overlengthening (*Sphaceloma manihoticola,* Bittancourt and Jenkinns, 1950) in ten plants from the useful area in each plot, at four and six months after emergence, according to the scale proposed by Lozano (1978), quoted by Silva (1981) and c) mean tuberous root yield, expressed in kg ha^{-1}, obtained by weighing the roots of all the plants harvested from the useful area of the experimental plot.

The localities and years were considered as environments, producing a total of four environments: environment 1 corresponded to the experiment set up in *Maringá* in 1995/96; environment 2 represented the experiment in *Maringá*, 1996/97; environment 3 was the experiment set up in *Rolândia* in 1996/97 and environment 4 was the experiment set up in *Rolândia* 1997/98. The genotype effect was taken as fixed and the others as random (Cruz and Regazzi, 1997).

When the experimental data was obtained, a simple analysis of variance was performed in the different environments for the characteristic tuberous root yield and then joint analysis of variance, using the residual mean squares that were not higher than the 7:1 ratio, according to Gomes (1990). Where there was significance for the genotype x environment interaction, the Plaisted and Peterson (1959) and Kang (1988) stability assessment methodologies were used with the computer resources of the Genes Program (Cruz, 1997).

The methodology proposed by Plaisted and Peterson (1959) quantifies the relative contribution of each genotype to the genotypes interaction x environments and identify those with higher stability. Through this method, the stability parameter θ_i was obtained: the lower magnitudes detected, the more stable genotypes were.

The method proposed by Kang (1988) involves the production averages of tuber roots genotypes and the stability parameter proposed by Plaisted and Peterson (1959). It means, initially, to sort by decrescent order genotypes in relation of the tuber roots average production. After that, to accomplish the genotypes, sorting by crescent order, in relation to the stability parameter adopted. Then, add both results and the one that presents the lower sum will be considered the more stable genotype and yielder.

The data obtained on diseases such as bacteriosis incidence and overlengthening symptoms were analyzed by descriptive statistics.

Results and discussion

Table 1 shows the cultivar reaction for bacteriosis and over lengthening. The *Branca de Santa Catarina*, Fibra, IAC 47-86, IAC 144-86 and IAC 187-86 cultivars were highly susceptible to bacteriosis but the IAC 169-86 and IAC 183-86 cultivars were highly resistant, while the IAC 12 and IAC 109-86 cultivars showed medium resistance to the *Xanthomonas axonopodis* pv. *manihotis* pathogen (Dye *et al*. 1980). Research by Vidigal Filho *et al*. (2000) and Rimoldi (2000) also showed low resistance to bacteriosis in *Branca de Santa Catarina* and Fibra cultivars. Vidigal Filho *et al*. (2000) emphasized that the Fibra cultivar, even though showing low resistance to bacteriosis, is still one of the cultivars most exploited by cassava farmers in the northern and northwestern *Paraná*, and also has good tuberous root yield.

Regarding susceptibility to overlengthening, Table 1 shows that *Branca de Santa Catarina*, IAC 12, Fibra, IAC 109-86, IAC 144-86 and IAC 169-86 cultivars showed medium resistance to the pathogen. The IAC 183-86 and IAC 187-86 cultivars showed high susceptibility while the IAC 47-86 cultivar was outstandingly resistant to overlengthening. Rimoldi (2000) also showed medium susceptibility to over lengthening in the *Branca de Santa Catarina*, IAC 12 and Fibra cultivars.

Table 1. Reaction to bacteriosis and over lengthening in nine cassava cultivars assessed in *Maringá* and *Rolândia,* Paraná State

Cultivars	Susceptibility to bacteriosis	Susceptibility to overlengthening
Branca de Santa Catarina	High	Medium
IAC 12	Medium	Medium
Fibra	High	Medium
IAC 47-86	High	Low
IAC 109-86	Medium	Medium
IAC 144-86	High	Medium
IAC 169-86	Low	Medium
IAC 183-86	Low	High
IAC 187-86	High	High

Table 2 shows the mean values for tuberous root yield of nine cassava cultivars assessed in four environments in *Maringá* and *Rolândia*. There is variation in the means for environment, with values oscillating from 22,375 to 12,809kg.ha^{-1} in 1996/97 and 1997/98 respectively, in *Rolândia*.

When the cultivar yield by environment is further analyzed, the IAC 169-86, Fibra and IAC 47-86 cultivars were outstanding in the experiments carried out in *Maringá*, in 1995/96, the IAC 169-86, presenting tuberous root yields superior to the mean by environment and to the general mean. For the year 1996/97, the cultivars IAC 183-86, Fibra and IAC 169-86 were outstanding for tuberous root yield, with mean values superior to the mean by environment and to the general mean. The Fibra, IAC 169-86 and IAC 183-86 cultivars were superior for tuberous root yield in the experiments assessed in *Rolândia*, both in 1996/97 and 1997/98, also with mean values higher than the mean by environment and the general mean of the experiment (Table 2).

When the mean yield of the cultivars is taken into consideration, there was a considerable oscillation in values and the most productive cultivar was Fibra, with a mean production of 25,096kg ha^{-1} while the least productive cultivar was IAC 187-86 which produced a mean of only 8,912kg ha^{-1} (Table 2). The most productive cultivars were Fibra, IAC 169-86 and IAC 183-86, in descending order. Lorenzi *et al*. (1996) obtained similar results when the same cultivars were assessed in the state of *São Paulo*.

Table 2. Tuberous root yield means, in kg.ha^{-1}, of nine cassava cultivars assessed in *Maringá* and *Rolândia,* Paraná State

Cultivars	Environments				Mean
	1	2	3	4	
Branca de Santa Catarina	13,125	19,668	17,659	5,093	13,886
IAC 12	18,222	22,128	19,319	7,387	16,764
Fibra	23,025	24,043	33,203	20,115	25,096
IAC 47-86	18,995	20,469	21,273	9,405	17,535
IAC 109-86	14,370	18,867	13,785	6,524	13,386
IAC 144-86	12,920	20,269	25,601	17,430	19,055
IAC 169-86	24,015	23,452	30,859	18,438	24,191
IAC 183-86	15,830	24,902	29,850	20,360	22,735
IAC 187-86	6,288	9,004	9,380	10,528	8,912
Mean	16,310	19,523	22,375	12,809	17,554

1- Fazenda Experimental Iguatemi (FEI), agricultural year 1995/96; 2- Fazenda Experimental Iguatemi (FEI), agricultural year 1996/97; 3- Cooperativa Agricultural de *Rolândia* (Corol), agricultural year 1996/97; 4- Cooperativa Agricultural de *Rolândia* (Corol), agricultural year 1997/98

Table 3 shows the results of the joint variance analysis for tuberous root yield, for the experiments carried out in *Maringá* and *Rolândia*. All the environments could be tested in the joint analysis of variance, as the division of the greatest value by the least of the mean square of the residue was not higher than 7:1 (Table 3).

There were significant differences for genotypes and for genotype x environment interaction, considering the tuberous root yield (Table 3). The significance of this interaction indicates that the cultivars did not behave similarly in the different environments assessed. Adaptability and stability studies were carried out using the methodologies by Plaisted and Peterson (1959) and Kang (1988) to reduce the significant effects of the genotypes by environment interaction.

Table 3. Joint analysis of variance of the tuberous root yield characteristic of nine cassava cultivars assessed in *Maringá* and *Rolândia,* Paraná State

F.V.	G.L.	Mean square PRA
Blocks/Environments	12	11,9193
Environments (A)	3	651,3859
Genotypes (G)	8	469,4670**
GxA	24	51,5194**
Residue	96	13,2294
Mean		17,9517
C.V. (%)		20,2612

** significant at levels of 1% probability for the F test

Table 4 shows the stability estimates by the method proposed by Plaisted and Peterson (1959) for the cassava tuberous root yield trait, for the experiments carried out in *Maringá* and *Rolândia*. The most stable cultivars by this methodology were IAC 169-86, IAC 147-86 and *Branca de Santa Catarina*, because they had the lowest values for the θ_i estimate, with percentage values of 6.282, 7.495 and 9.381, respectively (Table 4).

It is important to point out that Cruz and Regazzi (1997) stated that the most stable cultivars are not always the most productive, when analyzed by this methodology. An example of this is that, from the three most stable cultivars by this methodology, only IAC 169-86 presented a good yield mean for tuberous root, which indicated that, in the methodology by Plaisted and Peterson (1959), there is no agreement between yield and stability. Disagreement between yield and stability was also observed by Monge (1981) when assessing bean cultivars, by Vendruscolo (1997) when studying popcorn genotypes, by Daros and Amaral Junior (2000) when assessing sweet potato accession, by Rimoldi (2000) when studying cassava cultivar stability and by Vilhegas *et al*. (2001) when studying stability in corn hybrids.

Table 4. Stability estimates of tuberous root yield of nine cassava cultivars, assessed in *Maringá* and *Rolândia*, Paraná State, following methodology by Plaisted and Peterson (1959)

Cultivars	Stability estimate	
	θ_i	θ_i (%)
Branca de Santa Catarina	10,617	9,381
IAC 12	13,035	11,518
Fibra	21,411	18,918
IAC 47-86	8,482	7,495
IAC 109-86	12,179	10,761
IAC 144-86	11,660	10,303
IAC 169-86	7,109	6,282
IAC 183-86	12,765	11,279
IAC 187-86	15,913	14,060
Mean	12,575	

Table 5. Stability estimates of tuberous root yield in nine cassava cultivars, assessed in *Maringá* and *Rolândia*, Paraná State, following methodology by Kang (1988)

Cultivars	Estimate of θ_i (%)	Classification of θ_i (%)	Mean*	Classification of storage root mean	Sum**
Branca de Santa Catarina	9,381	3	13,886	7	10
IAC 12	11,518	7	16,764	6	13
Fibra	18,918	9	25,096	1	10
IAC 47-86	7,495	2	17,535	5	7
IAC 109-86	10,761	5	13,386	8	13
IAC 144-86	10,303	4	19,055	4	8
IAC 169-86	6,282	1	24,191	2	3
IAC 183-86	11,279	6	22,735	3	9
IAC 187-86	14,060	8	8,912	9	17

* Storage roots mean yield, expressed in $kg.ha^{-1}$; ** Sum of the classifications involving the θ_i (%) classification and the classification of storage roots mean yield

Table 5 shows the stability estimates by the method proposed by Kang (1988) for the cassava tuberous root trait in the experiments carried out in *Maringá* and *Rolândia*.

When the stability and yield estimates were analyzed together, the IAC 169-86 and IAC 47-86 cultivars showed the lower classification sums, and were considered the most stable and productive (Table 5).

When analyzed separately, the IAC 169-86 cultivar was more stable by the Plaisted and Peterson (1959) methodology and was also considered the second most productive cultivar, considering tuberous root yield (Table 5).

The IAC 47-86 cultivar, placed because of its stability, ranked second by the Plaisted and Peterson (1959) methodology and thus is in the second place in the ranks sum, as in Table 5.

Considering the behavior stability for the tuberous root yield characteristic, the IAC 169-86 cultivar was a stable and productive material and also resistant to bacteriosis and presented medium susceptibility to overlengthening. It was therefore suitable for recommendation to cassava producers in the northern and northwestern *Paraná*.

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