

COEFFICIENT OF VARIATION: A NEW APPROACH FOR THE STUDY IN MAIZE EXPERIMENTS

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- **ABSTRACT:** The magnitude of the variation coefficient (CV) is insufficient to validate the quality of the experiment, regardless of the number of treatments, repetitions and effect of treatments. The objective was to develop a new approach to the study of coefficient of variation, as well as evaluations of these nuances with applicability in new scientific research. The study was conducted via computer simulation. The replicates (r) ranged from 2, 3, 4, 5, 10 to 20. The treatment number (t) ranged from 5, 10, 15, 20, 25 and 30. In each of these combined scenarios we have the variation of 25 different CVs, ranging from 1, 3, 5, 7, ..., 49 to 51 %. It was imposed the variation of 11 treatment effects 0, 240, 480, 720, ..., 2000, 2400 kg ha⁻¹, totaling 9,900.00 scenarios. The type I error is statistically invariant in the scenarios studied. With high treatment effect the CV has no implications on the power of the test (1-β). The results obtained in this research reveal that experiments with a high percentage of CV are sufficient to obtain high probabilities of the power of the F test, which do not compromise the complementary analyzes.
- **KEYWORDS:** Number of treatments and repetitions; treatment effect; magnitude of the CV.

1 Introduction

Experimentally, the CV is a variable used to quantify experimental precision. Many random variables affect the magnitude of CV, most of which are highlighted in the literature in various articles, reports and technical and scientific reports. The CV is defined as the estimate of the experimental error as a percentage of the mean estimate, it is one of the statistical measures used by the researchers in the evaluation of the experimental precision.

The existence of a coefficient that estimates the experimental precision has great utility for scientific research since results of scientific works are realized and compared (LÚCIO *et al.*, 1999; SCAPIM *et al.*, 1995). Another advantage of the CV is to be a relative number, independent of the unit of measurement or measurement of the variables responses collected

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in the experiment (GOMES, 1987). The authors Steel and Torrie (1980) argue that the researcher should be aware of the variable studied to be able to identify if the variation of chance is high or low. Mead and Curnow (1986) argue that for variables where values can be positive and negative, the mean can tend to zero, leading to extremely high CV estimates. These authors report the importance of CV to determine the number of repetitions needed to observe differences between means of treatments with a known probability.

In literature, we can observe many researches that investigated the CV as (SCAPIM *et al.*, 1995; BORGES and FERREIRA, 2003; CARGNELUTTI FILHO and STORCK 2007; GIRARDI *et al.*, 2009; OLIVEIRA *et al.*, 2013; SILVA *et al.*, 2012). Some authors available the magnitude of CV to the possibility a comparison with others experiment. This comparison had been realized with much care.

In decisions of a hypotheses test, there are hits and misses. Reject the null hypothesis (H_0) when is true, it is defined as type I error probability, represented for α and fixed by the researcher. Additionally, another wrong decision is to accept the hypothesis of H_0 when it is false (RAMOS and FERREIRA, 2009; SOUSA JUNIOR and FERREIRA, 2012; GIRARDI *et al.*, 2009). The power of the test ($1 - \beta$) is correct when H_0 is false, in situations with different magnitudes of treatment effects, variation occurs in the type II error, which directly implies power of the test within each level of treatment effect and number of replicates, number of treatment and magnitude of treatment effect.

The main nuances that guide this study are related to the following assumptions: a) the variables considered up to now to evaluate the experimental quality are insufficient. b) high test power may be associated with high CV's. c) the type I error (α) in ANOVA maintained rates of 5% and did not reveal bias according to the scenarios. The magnitude of the CV insufficient to validate the quality of the experiment, not being independent of the number of treatments, repetitions and treatment effect. The aim of this research was realized a study of to CV in the scenarios agronomics by computational simulation.

2 Material and methods

The research was initiated with the collected information in the site of National Supply Company (CONAB), available at <https://www.conab.gov.br/>, to the estimated crop of maize 2017/2018 at Brazil. The information collected was referent mean of yield grains at Brazil. Initially, the averages of all the states of the five Brazilian regions were collected, with these values were calculated the average yield, which was 4000 kg ha⁻¹. With this information of average, a study was carried out on the magnitude of the effects of the treatment.

Scenarios studied were based on agricultural experiments, planned and applied through Monte Carlo computational simulation with 2000 resampling. Each scenario had the variation for the number treatment, replication, variation coefficient and for the treatment effect. The replications (r) variation 2, 3, 4, 5, 10 and 20. For the factor number of treatment (t), experiments with 5, 10, 15, 20, 25 and 30 were simulated.

In this sequence, the scenarios were studied from the combination of $t \times r$, as soon as we have 6 different scenarios with variation of r , thus fixing 5 treatments we have combinations of $t \times r$: 5×2 , 5×3 , 5×4 , 5×5 , 5×10 and 5×20 , for example, totaling 36 combinations. In each of these 36 scenarios we have the combined variation of 25 CV's, ranging from 1, 3, 5, 7, ..., 49, 51%. We set up the scenarios with 11 treatment effects

varying from 0, 240, 480, 720, ..., 2000, 2400 kg ha, in combination with the same number of treatments, repetitions and CV's, totaling 9,900 combinations.

The estimation of the treatment effect 0 was used to calculate the probability of type I error (α), that is, to reject H_0 when H_0 is true. Type I error was calculated for all combinations of $t \times r$. The statistic of standard error of the mean (SEM) was estimate for the probability of type I error (Equation 1).

$$\varepsilon_p = \frac{\hat{\sigma}}{\sqrt{n}} \quad (1)$$

To verify the number of correct decisions, the statistic of $1 - \beta$ (test power) was used, which is related to the type II error, so the probabilities of significance are estimated for the effects of treatments dimensioned in each scenario and CV, specifically.

The completely randomized design was adopted because it is the simplest of all the designs and is the most used in the literature for this purpose (BORGES and FERREIRA, 2003). The linear model used was:

$$Y_{ij} = \mu + \tau_i + \varepsilon_{ij} \quad (2)$$

where: Y_{ij} = is the value simulation in j-ésima replication of treatment i ($i= 1, 2, \dots, n$) in replication j ($j = 1, 2, \dots, n$); μ = is a general constant to have the determined coefficient of variation; τ_i = is the parametric effect of treatment i , stipulated for $\sum_{i=1}^t \tau_i = 0$; ε_{ij} = is the random error, where ε has \sim NID ($0; \hat{\sigma}_\varepsilon^2$). The nominal value of significance α , equal to 5%.

In order to increase the discussion of the results, the authors used a very usual CV classification with a high number of citations, used for the corn grain yield variable. The classification of CV according to the article by Scapim *et al.* (1995) is given as follows: low 10%, average 10 - 22%, high 22 - 28% and very high > 28%, which according to Google Scholar has more than 276 citations.

The results for the study of CV behavior for the scenarios with 5, 10, 15, 20, 25 and 30 treatments are shown in figures 3, 4, 5, 6, 7 and 8. The figures were prepared individually by fixing the number of replicates and treatments, with variation for magnitude of CV's as a function of treatment effects and probability of significance in the F test of the analysis of variance. Initially for description of the results we set 0.8 of probability as critical point in $1 - \beta$ to detect the treatment effect when H_0 is false.

3 Results

To estimate the probability of error type I in each of the scenarios, for rejection of H_0 when H_0 is true, the simulation analyzes were performed with zero treatment effect (without effect), so any and all likelihood of rejection of H_0 becomes misleading. The results are shown in figures 1 and 2, for the first figure we have the experiments with 5 (A), 10 (B) and 15 (C) treatments, in the second for 20 (A), 25 (B) and 30 (C) treatments.

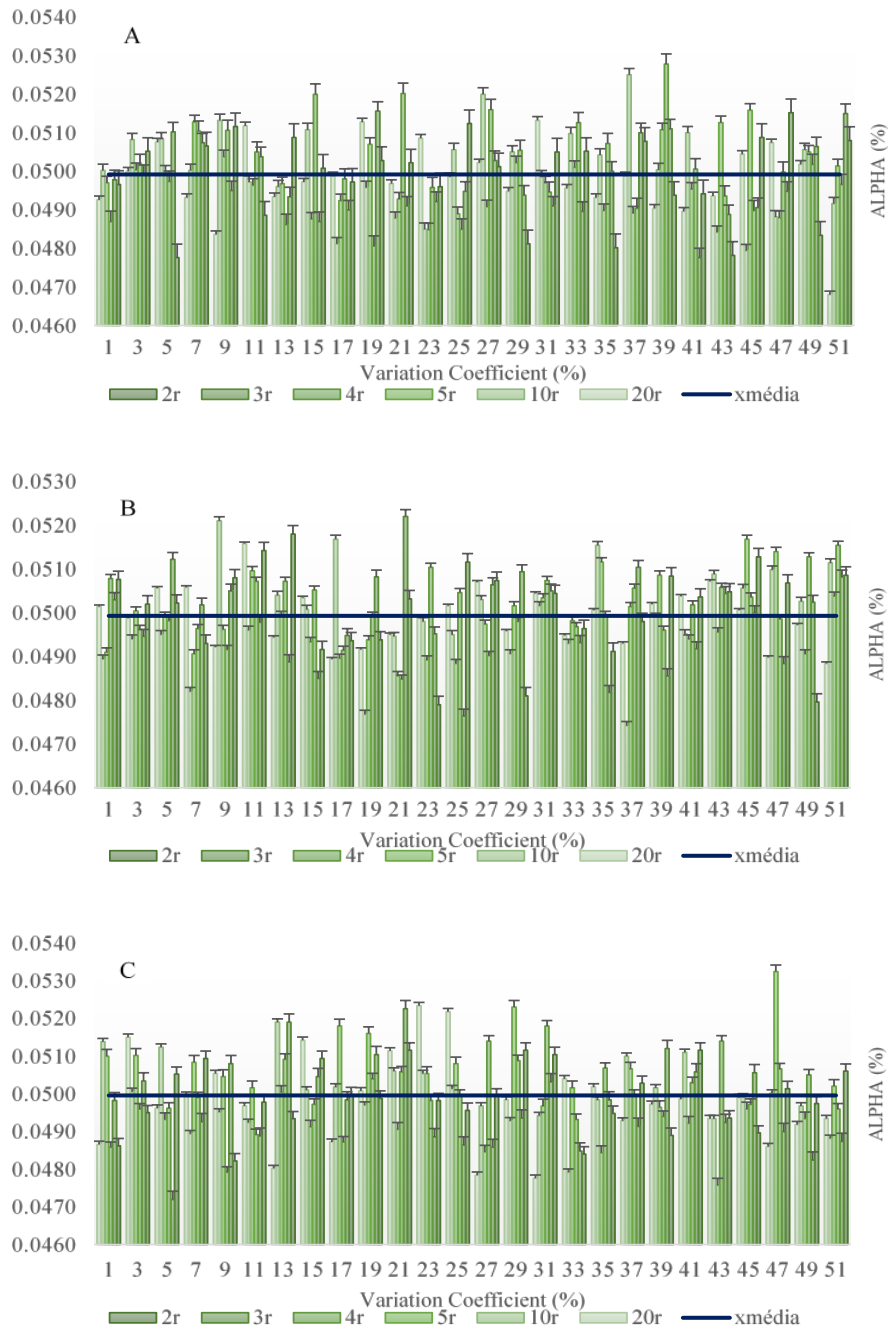


Figure 1 - Type I error rate (α) for treatment effect 0 (no effect) as a function of the coefficient of variation for the scenarios with 5 (A), 10 (B) and 15 (C) treatments.

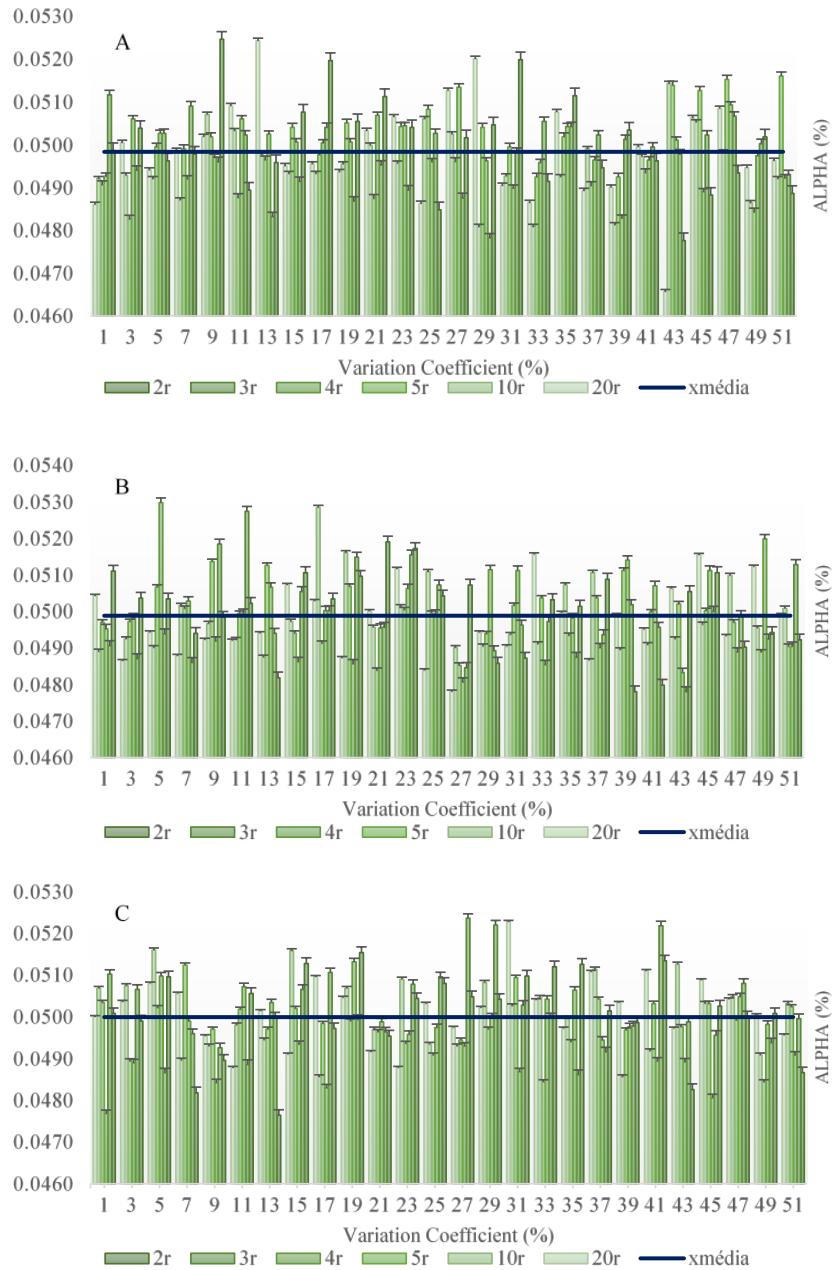


Figure 2 - Type I error rate (α) for treatment effect 0 (no effect) as a function of the coefficient of variation for the scenarios with 20 (A), 25 (B) and 30 (C) treatments.

The type I error showed low rates of variation for the experiment with 5 treatments (Figure 1 and 2) with a mean of $p = 0.0499$, that is, below the 5% probability rate, with a minimum value of $p = 0.0468$ and a maximum value of $p = 0.0528$. The occurrence of type I error for scenarios with 10 treatments revealed a mean of $p = 0.0499$, a scenario with a minimum value of $p = 0.0472$ and a maximum of $p = 0.0532$. For the scenarios with 15 treatments we obtained a mean value of $p = 0.050$, a scenario with a minimum of $p = 0.0474$ and a maximum of $p = 0.0522$. In the scenarios for 20 treatments, an average value of $p = 0.0498$ was obtained, a scenario with a minimum value of $p = 0.0466$ and a maximum value of $p = 0.0525$. With 25 treatments the mean value of $p = 0.0499$, a scenario with a minimum value of $p = 0.0478$ and a maximum value of $p = 0.0530$. With 30 treatments the mean value of $p = 0.0500$, a scenario with a minimum value of $p = 0.0477$ and a maximum value of $p = 0.0524$.

The results of scenarios with 5 treatments are in the Figure 3. In the first scenario with 5 treatments and 2 replicates we observed for a correct decision >0.8 , the treatment effect should be $>960 \text{ kg ha}^{-1}$ in low CVs. In CV's high we have a reduced probability of 0.5 for there to be significance in the source treatment. In experiments of three, four and five replicates we observed with 0.8 of probability significance between treatments at effects $\geq 480 \text{ kg ha}^{-1}$ in conditions with low CV's. In the high effects between treatments the power of the test remains high, in situations of CVs classified in medium and high. Become characteristic with increasing number of repetitions. The three scenarios mentioned above are most commonly employed in experimental researches involving evaluations in the field of grain yield in most species of agronomic interest.

In the experimental scenarios of 10 and 20 repetitions the power of the test to detect significance between treatments with probability >0.8 occurs for all effects, in situations of low CVs. In the mean CV, we observed that 7 and 8 were significant of the 10 treatment effects. With high and very high CVs and effect $>1200 \text{ kg ha}^{-1}$ between treatments, the probability significance follows >0.8 .

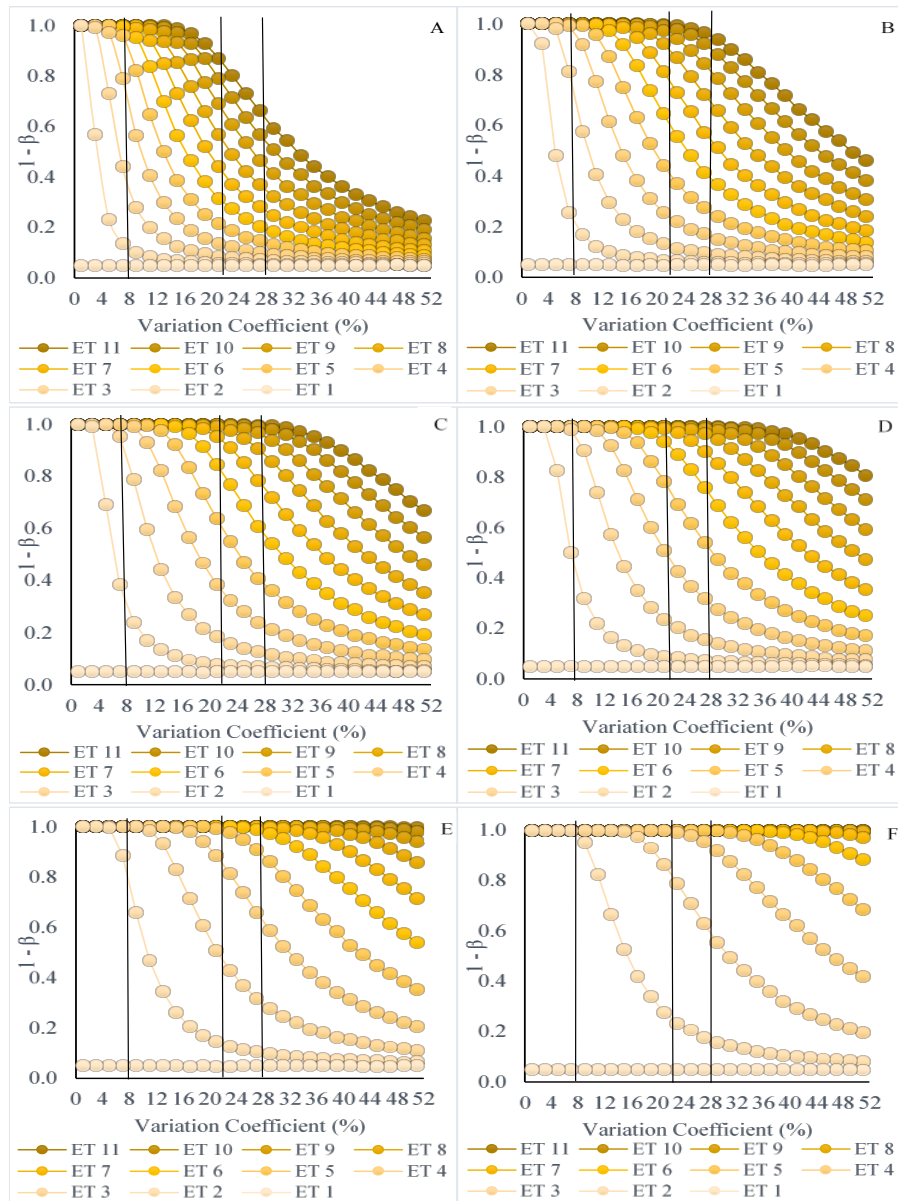


Figure 3 - Simulation of the effects of treatments ranging from ET 1 = 240, ET 2 = 480, ET 3= ,..., = ET 11 = 2400 kg ha⁻¹ of maize grains as a function of the variation coefficient (CV%) and the power of the test (1-β) for scenarios with five (5) treatments and 2-A, 3-B, 4-C, 5-D, 10-E and 20-F repeats. *Vertical lines are from the classification of the coefficient of variation proposed by Scapim *et al.* (1995) proposed for grain yield in maize.

The results of scenarios with 10 treatments are in the Figure 4. For the first scenario with two replicates, we verified the power of the test with probability >0.8 in high CVs only when high treatment effects are observed, such as 2160 and 2400 kg ha⁻¹. CV's very high the significance in the *F* test becomes ≥ 0.5 regardless of the effect. In experiments that have low differential effect between treatments (240 and 480 kg ha⁻¹) CVs below 6% are required for experiments with two replicates.

In the scenarios with three, four and five repetitions the probability >0.8 in nine of the 10 treatment effects, with low CV's. At four and five repetitions and effects >240 kg ha⁻¹, there is a 100% likelihood of significance. In the mean CV range we detected in the power of the test with probability >0.8 in effects greater than 960, 720 and 480 kg ha⁻¹ in the experiments with three, four and five repetitions. With effects of 1680, 960 and 720 kg ha⁻¹ in experiments of three, four and five repetitions the power of the test has a probability >0.8 of significance in *F*, although the CV is high.

In the experimental scenarios of 10 and 20 repetitions, regardless of the effect the power of the test presented a probability of 1.0 being significant in the source of variation treatments, with low CVs. With effect >240 kg ha⁻¹ the probability of the power of the test is >0.82 of significance in the source treatments in experiments with average CV. The effects >480 kg ha⁻¹ are required to be raised the likelihood of significance at source treatments, in situations of high CV's. Effects of 1200 kg ha⁻¹ are required for test power to have high hit rates and significance in treatments with very high CVs $>50\%$.

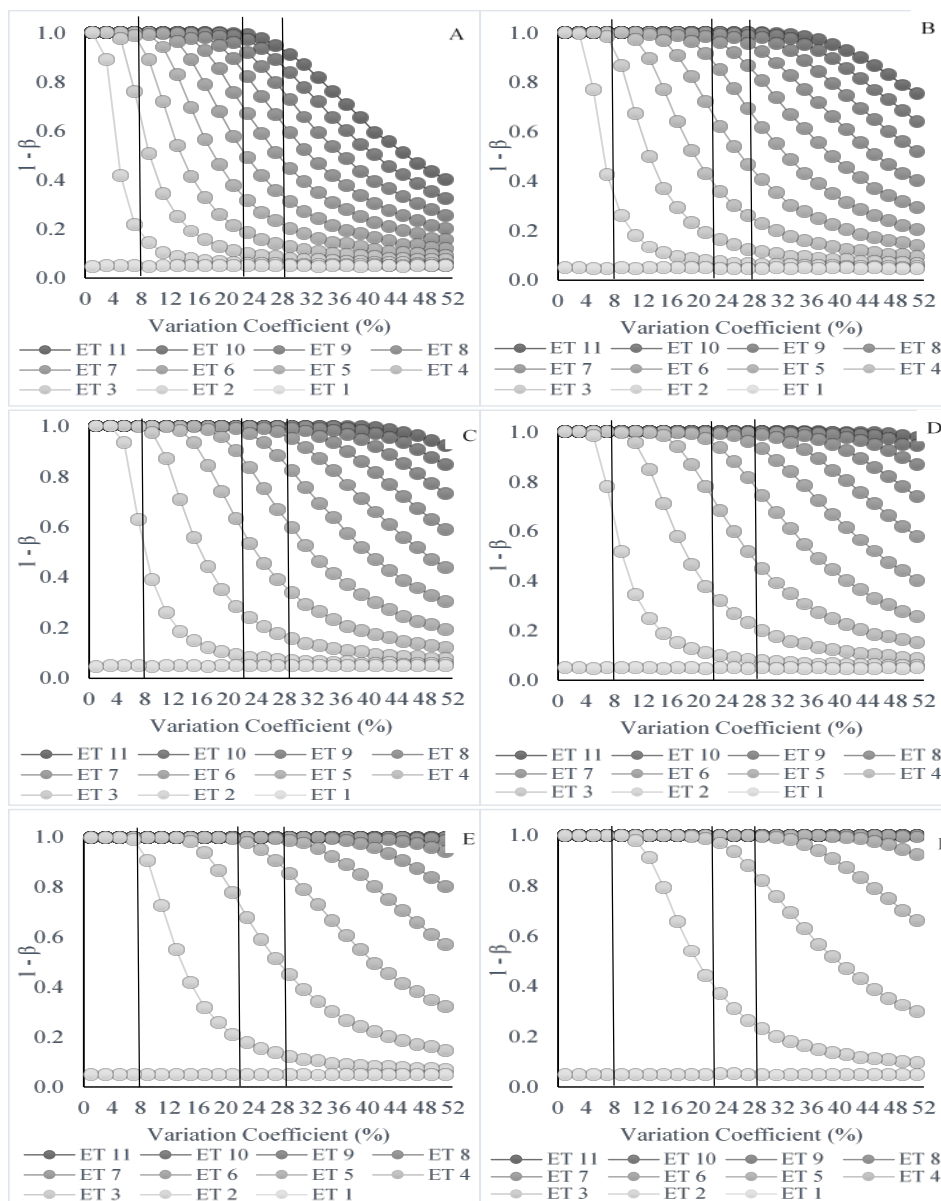


Figure 4 - Simulation of the effects of treatments ranging from ET 1 = 240, ET 2 = 480, ET 3 = ..., = ET 11 = 2400 kg ha⁻¹ of maize grains as a function of the variation coefficient (CV%) and the power of the test (1-β) for scenarios with 10 treatments and 2-A, 3-B, 4-C, 5-D, 10-E and 20-F repeats. *Vertical lines are from the classification of the coefficient of variation proposed by Scapim *et al.* (1995) proposed for grain yield in maize.

The results of scenarios with 15 treatments are in the Figure 5. With the first scenario of two replicates, it can be observed that effects $>480 \text{ kg ha}^{-1}$ the power of the test revealed a probability of significance for assertive treatment >0.85 , in low CV's. In the mean CV range, the high probability in the test power is maintained for treatments $>960 \text{ kg ha}^{-1}$. In more extreme scenarios the effects $>1440 \text{ kg ha}^{-1}$ are required to observe significance with high CV's, in this logic, experiments with CV's close to 50% reduce the power of the test to less than 0.5 probability of significance for treatment.

In scenarios of three, four and five replicates, experiments with effect $>240 \text{ kg ha}^{-1}$ the power of the test revealed probability >0.8 of significance for treatment, low CV. The treatment effects of 720 and 480 kg ha^{-1} are important to remain high the probability of the power of the *F-test* in mean CV's. With treatment effects $\geq 2160, 1920$ and 1680 kg ha^{-1} the power of the test maintains the assertive probability of significance of the *F-test* in high CV's. In this sequence, the presence of very high CV's does not prevent the detection of significance for source treatment if the effects are high.

In the scenarios of 10 and 20 repetitions, we observe the power of the test with probability of 1.0 in all the effects, low CV's. Treatment effects $>240 \text{ kg ha}^{-1}$ are required to have high probability in the power of the test for the significance of treatment with *F test* in mean CV's. The effects above 480 and 240 for 10 and 20 repetitions relate to the power of the test above >0.8 probability, at high CV's. Regardless of the CV's if the effects of treatments are >960 and 480 kg ha^{-1} , the power of the test has a probability >0.9 of significance in the source of variation of treatments.

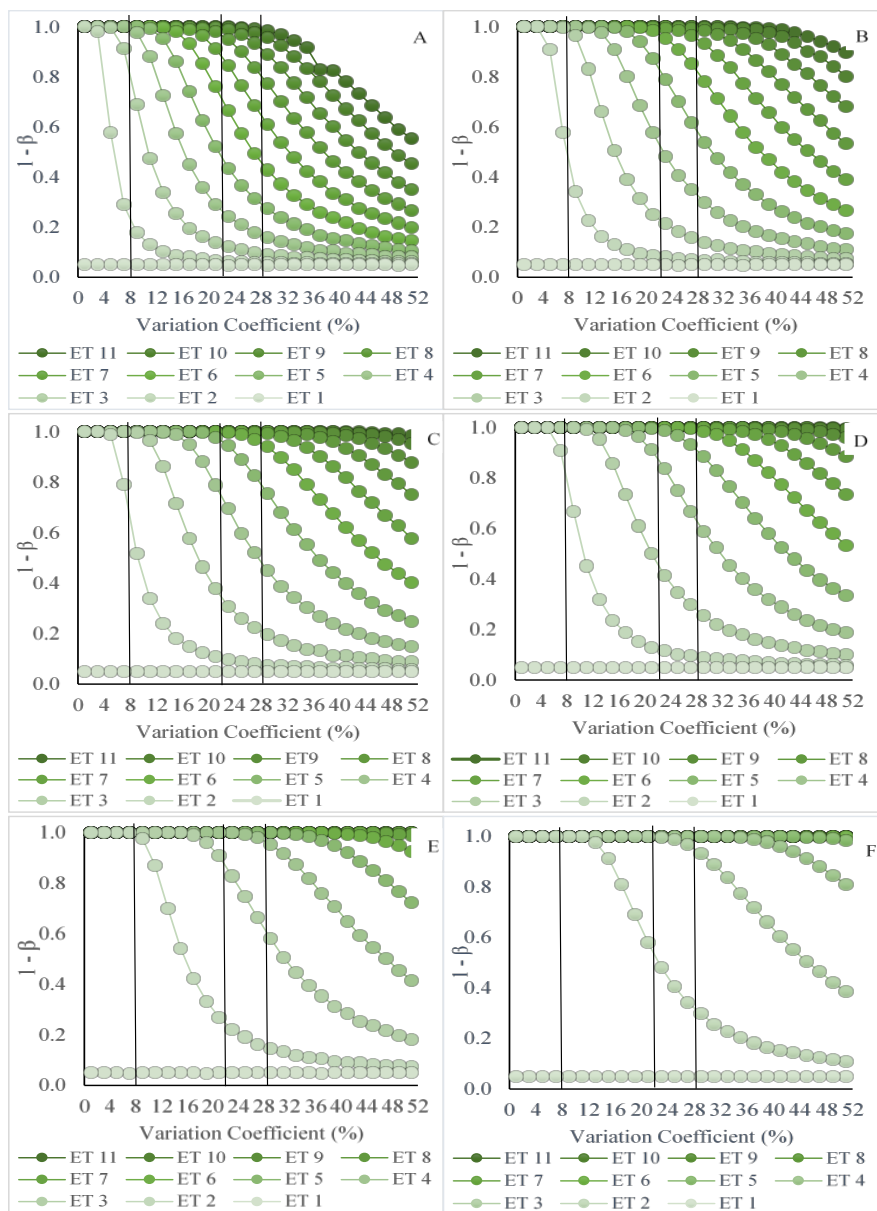


Figure 5 - Simulation of the effects of treatments ranging from ET 1 = 240, ET 2 = 480, ET 3 =, = ET 11 = 2400 kg ha⁻¹ of maize grains as a function of the variation coefficient (CV%) and the power of the test (1-β) for scenarios with 15 treatments and 2-A, 3-B, 4-C, 5-D, 10-E and 20-F repeats. *Vertical lines are from the classification of the coefficient of variation proposed by Scapim *et al.* (1995) proposed for grain yield in maize.

The results of scenarios with 20 treatments are in the Figure 6. In the first scenario with two replicates, treatment effects $>480 \text{ kg ha}^{-1}$ are required for the power of the test to reveal probability >0.9 of significance in low CV's. With effects of 240 and 480 kg ha^{-1} the power of the *test F* has probability $>0.65 <0.85$ of hits by the *F test* in CV's of 3 and 9%. The effects $>960 \text{ kg ha}^{-1}$ in the mean CV range, maintains the power of the *F-test* with probability >0.85 of assertive significance for treatment. In this sequence, with effects >720 and 960 the power of the test remains with probability >0.8 of significance in experiments of CVs >13 and $<17\%$. The effects of treatments above 1200 kg ha^{-1} are important for the power of the test to be >0.8 in high CV's. In extreme scenarios with very high CV's and with variation around 50%, the probability of test power is less than 0.7 regardless of the effects of treatments when two replicates are used.

In scenarios with three, four and five replicates all effects $>240 \text{ kg ha}^{-1}$ the power of the test has the probability is >0.7 of significance for treatment at low CV's. With three replicates the treatment effects should be $>480 \text{ kg ha}^{-1}$ for the power of the test to maintain high probability, in mean CV's. With four replicates, effects of 480 kg ha^{-1} , we observed the power of the test with probability >0.8 of significance for treatment in CV's less than 13%. In five replicates the $\text{CV} \geq 17\%$ test power maintains the probability of significance with effect of 480 kg ha^{-1} remains at 0.8. With very high CVs, the significance level is limited only to experiments that have a treatment effect of $<1440 \text{ kg ha}^{-1}$, mainly in the use of five replicates.

For the 10 and 20 repetition scenarios, the power of the test maintains a probability of 1.0, regardless of the treatment effect, in low CV's. In the scenario with 10 repetitions the effect of 240 kg ha^{-1} presented a linear reduction of the power of the test in CV of 17%, the probability was less than 0.5, for example. With 20 replicates the effects of treatments $>240 \text{ kg ha}^{-1}$ maintain the probability >0.95 of assertiveness in the power of the *F test* in high CV's. Experiments with 10 and 20 repetitions test power retains the probability >0.85 at effects ≥ 720 and 480 kg ha^{-1} , for CVs close to 50% or very high.

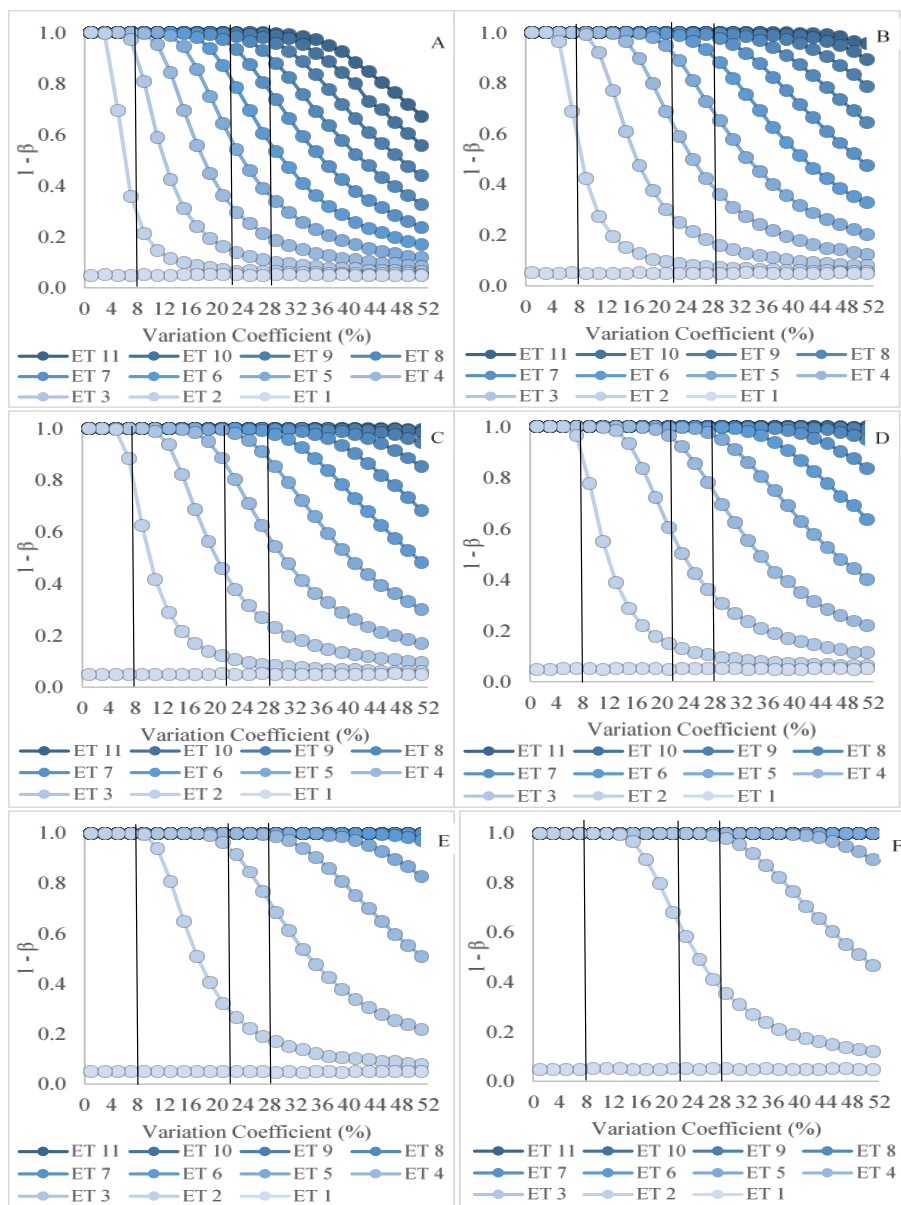


Figure 6 - Simulation of the effects of treatments ranging from ET 1 = 240, ET 2 = 480, ET 3 = ,..., = ET 11 = 2400 kg ha⁻¹ of maize grains as a function of the variation coefficient (CV%) and the power of the test (1-β) for scenarios with 20 treatments and 2-A, 3-B, 4-C, 5-D, 10-E and 20-F repeats. *Vertical lines are from the classification of the coefficient of variation proposed by Scapim *et al.* (1995) proposed for grain yield in maize.

The results of scenarios with 25 treatments are in the Figure 7. In the first scenario with two replicates, the treatment effect of 240 kg ha⁻¹ revealed the probability <0.5 for CV's >7%. All other effects, in low CV's, revealed probability >0.85. The effects 480 and 720 kg ha⁻¹ have a reduction of the probability, in CV's above 12%, the other effects remain with high probabilities. In the high CV interval, effects <960 kg ha⁻¹ revealed a probability <0.7 of the power of the test, the other effects presented high probabilities. With very high CV's the power of the test is reduced to practically all the effects of treatments evaluated in experiments with two replicates.

In scenarios with three, four and five repetitions, it was observed that effect <240 kg ha⁻¹ is likely <0.8 in the power of the test with CV's greater than 7%. In three replicates the power of the test has reduced assertiveness for the effects of treatments <480 kg ha⁻¹ in mean CV's. With four replicates, effects <480 kg ha⁻¹ and CV greater than 15% also indicated a probability <0.8 for the power of the test. In five replicates, effects below 480 kg ha⁻¹ associated with CV's greater than 19% revealed low power of the test, although all other effects remain with high probability. Similarities were observed for the high CV range, with three replicates effects <720 kg ha⁻¹ has probability <0.7, with four and five replicates effects <480 kg ha⁻¹ has a probability of <0.6 associated with the power of the test. With the effects of treatments >1440, 1200 and 960 kg ha⁻¹ for three, four and five repetitions the power of the test remains with high probability in very high CV's.

In the 10 and 20 repetition scenarios, the power of the test kept close to 1.0 the probability of the effects of treatments in low CV's. With 10 replicates, only effects <240 kg ha⁻¹ and CV's greater than 12% (medium) have reduced probability, however with double repetitions the probability remains ≤0.8. Any treatment effect >240 and 480 kg ha⁻¹ revealed the probability >0.85, regardless of the magnitude of the CV's. In this perspective, CV's high or very high do not provide any implication under the optics of the power of the *F test* in detecting the significance for treatment.

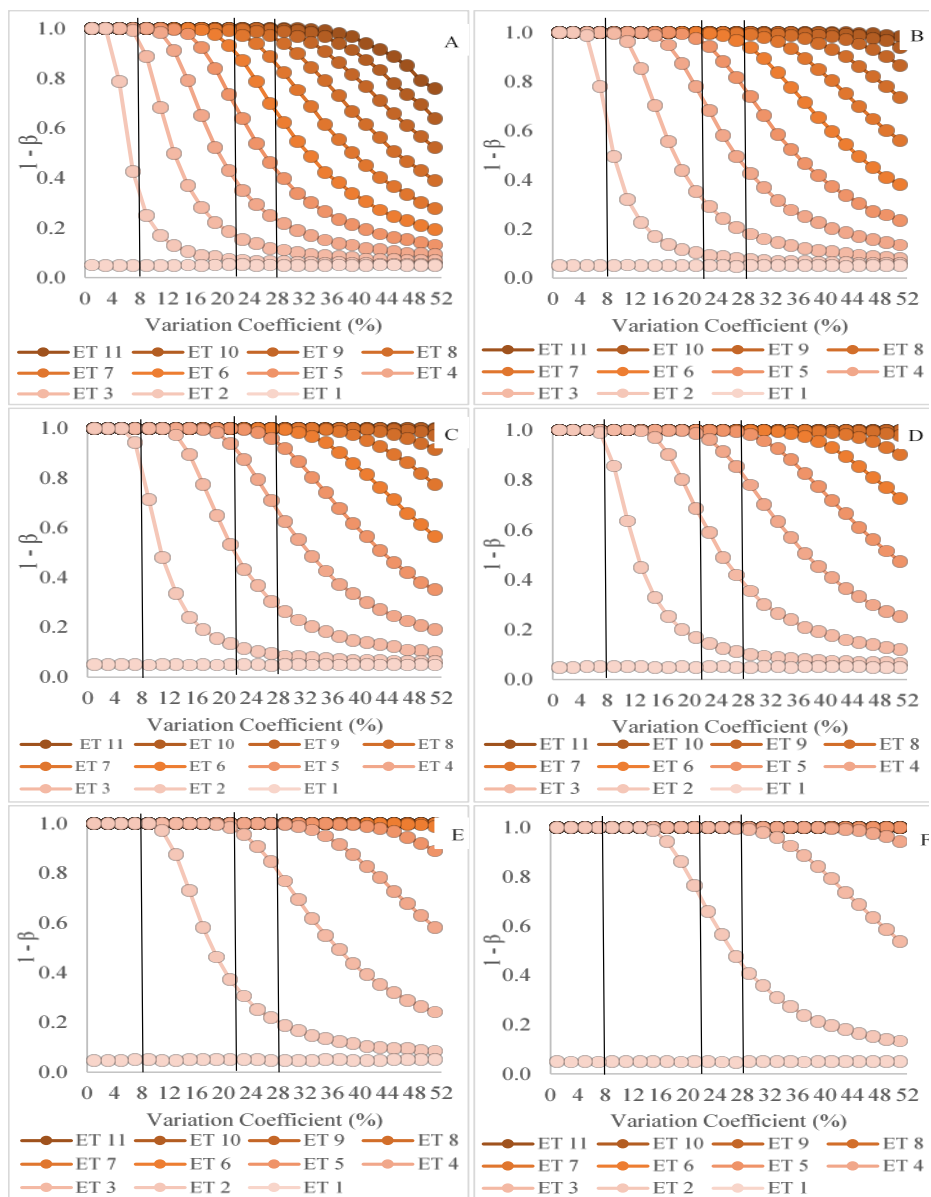


Figure 7 - Simulation of the effects of treatments ranging from ET 1 = 240, ET 2 = 480, ET 3 = ,..., = ET 11 = 2400 kg ha⁻¹ of maize grains as a function of the variation coefficient (CV%) and the power of the test (1-β) for scenarios with 25 treatments and 2-A, 3-B, 4-C, 5-D, 10-E and 20-F repeats. *Vertical lines are from the classification of the coefficient of variation proposed by Scapim *et al.* (1995) proposed for grain yield in maize.

The results of scenarios with 30 treatments are in the Figure 8. In the first scenario of two replicates, only with treatment effect $<240 \text{ kg ha}^{-1}$ the probability <0.5 , in CV's $>7\%$. The effects of treatments <480 and 720 kg ha^{-1} have a reduction in CV probability above 13 and 15%. All other effects remain with high probability. The effects of treatments $<960 \text{ kg ha}^{-1}$ revealed a probability <0.8 in high CV's. Treatment effects $>2160 \text{ kg ha}^{-1}$ are essential for the power of the test to maintain high probability in very high CV's, around 50% with two replicates.

In the scenarios with three, four and five repetitions, we observed that three replicates effects $<240 \text{ kg ha}^{-1}$, associated with CV's greater than 7% have a probability of <0.8 , whereas an effect of 480 kg ha^{-1} is required in a situation of the interval of CV's mean $>10\%$, on the other hand with four replicates the effects $<480 \text{ kg ha}^{-1}$ and the CV's greater than 17% also have their probability reduced and finally with five repetitions effects $<480 \text{ kg ha}^{-1}$ associated with larger CV's that 21% have low probability. All other effects remain with high probability of the power of the *test F* in the assertiveness of significance for treatment.

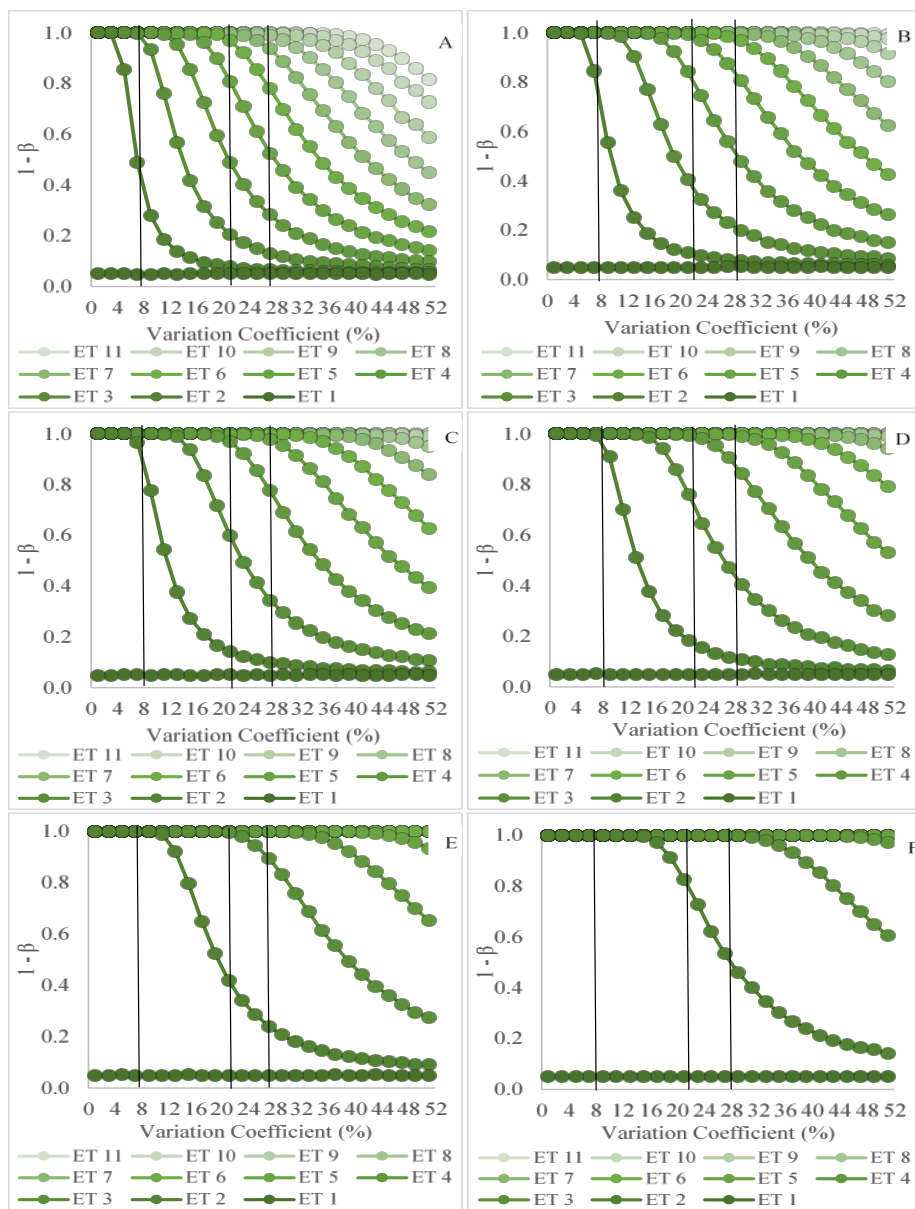


Figure 8 - Simulation of the effects of treatments ranging from ET 1 = 240, ET 2 = 480, ET 3, = ..., = ET 11 = 2400 kg ha⁻¹ of maize grains as a function of the variation coefficient (CV%) and the power of the test ($1-\beta$) for scenarios with 30 treatments and 2-A, 3-B, 4-C, 5-D, 10-E and 20-F repeats. *Vertical lines are from the classification of the coefficient of variation proposed by Scapim *et al.* (1995) proposed for grain yield in maize.

In the range of high CVs, with three replicates effects $<720 \text{ kg ha}^{-1}$ has a probability of <0.6 , with four and five replicates effects $<480 \text{ kg ha}^{-1}$ has a probability of <0.6 . With CV's close to 50%, the effects <1440 , 1200 and 960 kg ha^{-1} for three, four and five replications are likely to be reduced to less than 0.8 due to the increase in CV's. However, any effect higher than these has high probabilities of the power of the ANOVA *F test*.

In the scenarios with 10 and 20 repetitions, all the effects presented probability close to 1.0 in the low CV's. In the mean CV interval with 10 replicates, the effects of treatments below 240 kg ha^{-1} and CVs greater than 13% are likely to be <0.8 , with 20 replicates this effect (240 kg ha^{-1}) has a probability of around 0.8 with CV greater than 19%. In the range for high CV's significance detection is reduced only for treatment effects below 240 kg ha^{-1} , all other treatment effects maintain the odds around 1.0. With the presence of high CV's, in a 50% variation the treatment effects below 720 and 480 kg ha^{-1} the test presented low power in experiments with 10 and 20 repetitions. The power of the test remained high for all other effects of treatments.

4 Discussion

The presence of type I error is associated with significance detection for treatment purposes, or the source of variation, when it is not true. The results of error type I this study are pointed out by the *F test* are in agreement with (GIRARDI *et al.*, 2009; SOUSA JUNIOR and FERREIRA, 2012) with rates close to the 5% probability level fixed a priori. An important factor associated with the statistical tests to verify the hypothesis is that they present a type I error rate control. In all scenarios, the rates were near 5%.

The power of the *F test* keeps the probabilities high as the number of repetitions is extended, such tendencies are also evidenced when we increase the number of treatments, compared to the same number of repetitions, but the linearity is inferior compared to the increase of the number of repetitions. With the planned scenarios it can be shown that the power of the *F test* maintained high assertiveness in experiments with high variation, as soon as the elimination or uncertainty of the results of experiments with high CV's are not sufficient to assert on experimental quality, all the information characteristic of the experiment plan for the accomplishment of such comparative effect, and even so much caution must be taken.

The coefficient of variation is often used in agronomic and zootechnical experiments as an artifact of the experimental quality that determined a variable was analyzed in the experiment. As can be observed in the works of Faria Filho *et al.* (2016), which highlight that for each variable there is an ideal range of VC, such justifications are reported by Couto *et al.* (2013). CV for the main sugarcane variables with the median and pseudo-sigma method and concluded that each variable has an ideal range, always considering the nature of the studied variable, Silva *et al.* (2011) in a study of 38 experiments on pepper characteristics, Lima *et al.* (2004) proposed CV classification for some melon characteristics using information from 98 papers. Simioni *et al.* (2018) studied the variability of variables of zootechnical interest with the intent of classifying the CV according to its instability, in this study it was worked with publications from 1960 to 2016. Many papers in the literature, in general, bring the approach that CV is dependent above all on the structure of the experiment, number of repetitions, number of treatments and thus are expressed magnitudes for certain variables that serve as reference for conclusions about

experimental quality. In addition to these points, this work hypothesizes that the magnitude of CV has high rates of variation as a function of treatment effects, which is directly related to the probability of assertiveness of the ANOVA F -test. These results can be easily observed in the figures given in this article, where it is fixed number of replications and treatments according to the CV's and can of the test $(1-\beta)$, for 10 effects of treatments related to corn grain yield.

One of the main discussions that emerge in this paper is about CV's classifications - since high CV's are insufficient to reduce the power of the F test, if the effects of treatments are high. Currently in Brazil the cultivar release is conditioned to experimental trials of cultivation and use value (VCU) and of distinguishability, stability and homogeneity (DHE). The assumption for validation of the experimental trial (s) is linked to an estimate of CV less than 20%, thus the minimum standards established by the Ministry of Livestock and Supply (MAPA) for the validation of the test (s) as VCU or DHE are reached (BRASIL, 2011).

The results obtained in this research revealed that experiments with a high percentage of CV are not unlikely to obtain coherent and accurate conclusions, since scenarios with more than 4 replicates and 15 treatments maintain high test power F , that is, low probability of error type I, mainly for effects greater than 240 kg ha⁻¹, which are often obtained in VCU corn experiments (BUSANELLO *et al.*, 2015; BARETTA *et al.*, 2016a; BARETTA *et al.*, 2016b).

The number of replicates in the experiment demonstrates a close relationship with the probability of detecting significance between treatments in the experiment. This characteristic has been pointed Scapim *et al.* (1995); Silva *et al.* (2012); Cargnelutti Filho and Storck (2007); Resende and Duarte, 2007); Amaral *et al.* (1997); Lúcio *et al.* (1999) out, however, besides the number of replications, the treatment effects and the number of treatments also proved to be fundamental, since the power of the test revealed marked variations due to these sources of variation. For the experiments conducted on a plane with reduced number of repetitions, for example two, caution is needed, since if the effects of treatments are small, the power of the F test has a reduced likelihood of assertiveness, even for low CV's, this may imply absence of detection of significant differences in the source of variation treatment, eliminating the chances of performing complementary tests to ANOVA.

In the most simplistic scenario we can observe that high CV's practically make it impossible to detect significant differences between treatments, even considering the effects of high treatments, in a 5×2 plan only the high treatment effects maintain the test power at high rates, but for Most effects occur under low test power F , regardless of CV. From the moment we maintain this same number of treatments and we have one or two repetitions (3 r and 4 r) per treatment, we observed the increase in the power of the F test to 0.8 (80%) of significance in CV is low. On the other hand, with very high CV's the power of the test F , still detects with probability >0.8 in the effects >1920 kg ha⁻¹.

Conclusions

The type I error is statistically invariant in the scenarios studied. It kept rates around the set probability value.

The results obtained in this research reveal that experiments with a high percentage of CV are sufficient to obtain high probabilities of the power of the F test, which do not compromise the complementary analyzes.

The researchers' comparative action and the current coefficients of variation should be taken cautiously, since the classification points are insufficient for affirmations of experimental quality, since extreme scenarios reveal high test power F , but mainly dependent on the effect number of replicates and number of treatments.

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NARDINO, M.; PEREIRA, J. M.; MARQUES, V. T.; AVILA, F. C. D.; FRANCO, F. D.; BARROS, W. S. Coeficiente de variação: uma nova abordagem para o estudo em experimentos de milho. *Rev. Bras. Biom. Lavras*, v.38, n.2, p.185-206, 2020.

- *RESUMO: A magnitude do coeficiente de variação (CV) é insuficiente para validar a qualidade do experimento, independentemente do número de tratamentos, repetições e efeitos dos tratamentos. O objetivo foi desenvolver uma nova abordagem para o estudo do coeficiente de variação, bem como avaliações dessas nuances com aplicabilidade em novas pesquisas científicas. O estudo foi realizado via simulação em computador. As repetições (r) variaram de 2, 3, 4, 5, 10 a 20. O número de tratamentos (t) variou de 5, 10, 15, 20, 25 e 30. Em cada um desses cenários combinados, temos a variação de 25 CVs diferentes, variando de 1, 3, 5, 7, ..., 49 a 51%. Foi imposta a variação de 11 efeitos de tratamento 0, 240, 480, 720, ..., 2000, 2400 kg ha⁻¹, totalizando 9.900,00 cenários. O erro do tipo I é estatisticamente invariável nos cenários estudados. Com alto efeito de tratamento, o CV não tem implicações no poder do teste (1-β). Os resultados obtidos nesta pesquisa revelam que experimentos com alta percentagem de CV são suficientes para obter altas probabilidades de poder do teste F, o que não compromete as análises complementares.*
- *PALAVRAS-CHAVE: Número de tratamentos; número de repetições; efeito de tratamento; magnitude do CV.*

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