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Clonal composites as a strategy for mitigating the clones × environments interaction in eucalyptus

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SILVICULTURE

ABSTRACT

Background: One of the biggest challenges for breeders, especially for perennial plants, is to have strategies to reduce the risk of recommending new clones. One of the alternatives would be to use a mixture of clones, clonal compounds (CC), instead of monoclones (MC). This strategy has not yet been properly proven from experiments involving CC and MC simultaneously in different environments.

Results: The CC's contribution to the interaction was significant, although associated with a high MAI estimate (m^3. ha^{-1}. $year^{1}$). The CC's took better advantage of environmental stimuli than most MC's. The rick estimates in the CC recommendation were, in most situations, lower than those of the different monoclones.

Conclusion: The use of CC proved to be more efficient than the use of MC in mitigating the effects of the interaction of genotypes by environments, in recommending clones for forest exploitation.

Keywords: genotypes × environments interaction, plant breeding, quantitative genetics.

HIGHLIGHTS

The best clones to form a composite can be identified in STP or monoclones.
Composites took better advantage of differences in environmental stimuli than monoclones.
Risk estimates in the recommendation of composites are lower than for monoclones.
The use of composites is recommended to mitigate the clones x environments interaction.

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INTRODUCTION

It is evident that the environmental conditions of the past do not always reflect what will happen in the coming years (BEGNA, 2021). This challenge becomes even greater when working with perennials. In this case, the success of the clone will depend on environmental, spatial of temporal variations, after a few years. Many frustrations may occur under these conditions, that is, the clones that stood out in the past might not maintain their performance on a commercial scale. This frustration is reflected not only in the disappointment of the team involved in the process, but has enormous economic repercussions, above all because in large companies, the area planted with a determined clone can be quite expressive.

What alternatives are there for attenuating these errors in identification of new clones? One option that has been widely used is intense evaluation in well-conducted experiments in various different environments. Thus, normally, no clone will be recommended without its mean value having been obtained from dozens of replications (Troyer et al., 1996). This is important because the clones × environments interaction is of high magnitude for the eucalyptus crop in Brazil (Souza et al., 2020; Santos, 2012).

Unfortunately, the environments that have been used involve only the variation of locations, in which the environmental aspects, especially type of soil and management practices, are more predictable. The problem is more serious in regard to variation from one year to the next, because, obviously, the perennial plant remains under a given condition for some years. Little is known regarding the clones × years interaction for eucalyptus; however, in other species, this interaction appears to be considerable (Ferreira et al., 2014; Andrade et al., 2006).

Thus, the previous strategy, though important, does not resolve the unpredictability of the environmental conditions. One of the alternatives for mitigating this problem is the use of clonal composites (Rezende et al., 2019). In this case, the recommendation would not be only a single clone, but a mixture of clones. The expectation is that if some clone does not exhibit good performance, another will compensate, and the frustration of lack of success of a recommendation is attenuated.

A good strategy for testing this hypothesis is using experiments in a Single Tree Plot (STP) – clonal composites (CC) – in relation to the same clones that are in monoclonal plantings (MC), as performed by Rezende et al. (2019). From the results obtained, the relative contribution of the clones × environments interaction under the two conditions can be estimated. Although this information would be of great value, it has not yet been duly examined, above all with a large number of clones and environments, which may represent the future. In light of the above, the aim of this study was to estimate the contribution of the interaction of the composites in relation to their respective monoclones and determine if the composite formed from the monoclones or from STP has similar performance in relation to the estimates of parameters associated with the interaction.

MATERIAL AND METHODS

The data used were kindly provided by Suzano S.A. for evaluation of eucalyptus clones. Sixty (60) clones were evaluated at 3 years. The clones used are from different locations of origin from selection performed by the company, and belong to the species *E. urophylla, E. grandis*, or hybrids between them. The clones were evaluated in six locations including four states: Bahia, Espírito Santo, São Paulo, and Mato Grosso do Sul. These environments represent the main eucalyptus production regions in Brazil. Some details of the places where the experiments were carried out are in Table 1.

The experiments were conducted in two planting systems in a simultaneous and contiguous manner. The first in monoculture (MC) and the second in clonal composites (CC). They were set up in 2015 in a randomized block experimental design. The MC plots consisted of four rows with seven plants and three replications (only the ten central plants were evaluated in each replication), obtaining data from 30 plants per clone. In the CC, the plots consisted of a single plant (*single tree plot*), also with 30 replications. The plant spacing (Table 1) and the crop treatments were the same used in the operational plantings of the company.

The average annual increment MAI ($m^3.ha^{-1}.year^{-1}$) was estimated. With this character, analysis of variance of the data was performed according to the type of experiment (CC or MC) in each location. In the analyses, some situations were considered involving different numbers of clones to constitute the composites, i.e., 5, 10, 15, or 20. The clones in the first alternative were chosen based on the mean of the best clones in the STP. In other words, the five best clones in the overall mean in the CC experiment and the mean of these same clones in MC were identified. Thus, joint analysis was performed on six treatments: the means, in each environment, of the five clones in MC and of their mixture in CC. In the second alternative, the process was similar; however, the five best clones were identified to constitute the mixture from the overall mean of the experiments in MC, and the overall mean of these same clones was obtained in the STP experiment.

Table 1. Characterization of the locations in which the experiments were conducted within each region (Rezende et al., 2019).

Region	Location	Spa. (m)[1]	Alt. (m)[2]	AAR (mm)[3]	MAT (°C)[4]	Soil type[5]
Aracruz	Espírito Santo	3 x 2	37	1290	22.8-27.4	LAd
	Bahia	3 x 3	12	1320	22.2-27.2	PAd
Jacareí	Vale	3 x 2.5	646	1510	17.1-24.3	PVAd
	Capão Bonito	3 x 2	693	1292	17.0-24.3	LVd
Três Lagoas	Curucaca	3.6 x 2.3	350	1352	20.9-26.9	LVd
	Esperança	3 x 3	380	1352	20.8-26.9	LVd

[1]Planting Spacing. [2]Altitude. [3]Annual Average Rainfall. [4]Minimum and Maximum Month Average Temperature. [5]LAd: Dystrophic Yellow Oxisol; LVd: Dystrophic Red Oxisol; PAd: Dystrophic Yellow Ultisol; PVAd: Dystrophic Red Yellow Ultisol.

In synthesis, eight analyses of variance were performed using the means of the treatments in each location, according to the following model: $Y_{ij} = +m+t_i+l_j+tl_{ij}+\bar{e}_{ij}$ (Equation 1), where m is the overall mean, t_i is the fixed effect of the treatment i (i = 1,2,3, ..., 60), l_j is the fixed effect of the location j (j = 1,2, ..., 6), tl_{ij} is the fixed effect of the interaction between the i treatment and the j location, and $\bar{e}_{ijk}$ is the mean error. $\bar{e}_{ijk}$ was obtained by averaging the mean squares of the errors of the joint analyzes involving all clones in CC and MC at each location. It is worth noting that the errors were homogeneous. From these analyses of variance, the component of the treatment × location interaction (σ^2_{TL}) was estimated. Based on the mean values of the clones, the estimates of parameters that allow inferences in respect to the adaptability and stability and of the risk involved in the recommendation of each treatment were obtained. The methodologies for studying the interaction were:

a) Ecovalence estimate (W_i^2) (Wricke et al., 1964), which estimates the percentage contribution of each treatment – MC or CC – to the interaction. The estimator used was: $W_i^2 = \sum_{j=1}^{k}(\bar{y}_{ij} - \bar{y}_{i.} - \bar{y}_{.j} + \bar{y}_{..})^2 = \sum_{j=1}^{k}\widehat{TL}^2_{ij}$ (Equation 2), where $\widehat{TL}_{ij}$ corresponds to the sum of squares of the effect of the interaction of treatment i with environment j in which it was evaluated, $\bar{y}_{.ij}$ is the mean of treatment i in location j, $\bar{y}_{i.}$ is the mean of treatment i in all locations, $\bar{y}_{.j}$ is the mean of all the treatments in location j, and $\bar{y}_{..}$ is the overall mean.

Therefore, $\widehat{TL}^2_{ij}$ is the estimate of the effects of the interaction of the treatments in the environments.

b) Reliability index (I_i), which estimates the risk of adoption of each clone in CC or MC. This index was obtained by the Annicchiarico estimator (1992): $I_i = \bar{y}_{i.} - Z_{(1-a)}s_i$ (Equation 3), where $Z_{(1-a)}$ is the quantile of standardized normal distribution; a is the pre-established level of significance, in this case 0.25; and s_i is the standard deviation of the percentages of each clone.

c) The graph-based method of Nunes et al. (2005): the method allows estimation of the risk of adoption of a determined treatment. In this case, the mean data of the treatments in each environment should be standardized by the expression: $Z_{ij} = \left(\bar{y}_{ij} - \bar{y}_{.j}\right)s_{.j})$ (Equation 4), where $\bar{y}_{ij}$ is the mean of treatment i in location j, $\bar{y}_{.j}$ is the mean of location j, and $s_{.j}$ is the genotypic standard deviation among the mean values of the treatments in location j. The mean value of Z_i, the standard deviation (s), and the coefficient of variation (CV%) were estimated for each treatment.

All analyses were made using the R (R Core Team, 2015) and Genes (2006) (Cruz, 2013) statistical software.

RESULTS

As the results of the different numbers of clones to constitute the CC were very similar, it was decided to give greater emphasis to the presentation of the results using only 5 clones. It is observed that, with CC of size 5, for example (Table 2), only one clone would not be chosen as having the highest mean value in the two experiments (MC or CC). This is coherent, as the correlation estimate between the means of the clones in MC or CC, although differing between locations, was very high (r = 0.85**) in the mean of the six environments (data not shown).

As expected, the mean of the composite (CC) decreased with the increase in the number of clones involved in the respective composite, regardless of the selection having been performed in the STP experiment or monoclone experiment. The reduction, however, was not very expressive. If size 5 or size 20 CC was considered, with selection in the STP, the mean went from 71.57 $m^3.ha^{-1}.year^{-1}$ to 63.08 $m^3.ha^{-1}.year^{-1}$, that is, a reduction of 11.9%. In the other situation of selection in monoclones, the mean of the CC formed from size 5 (69.2 $m^3.ha^{1}.year^{1}$) and from size 20 (60.02 $m^3.ha^{-1}.year^{-1}$) showed a reduction of 13.3% (Table 2).

The average productivity ($m^3.ha^{-1}.year^{1}$) of CC decreased with the increase in the number of clones involved in the respective composite, regardless of whether the selection was carried out in the STP experiment or in the monoclone experiment. The reduction, however, was not very expressive. If size 5 or size 20 of the CC is considered, with selection at the STP, the average went from 71.57 $m^3.ha^{-1}.year^{-1}$ to 63.08 $m^3.ha^{-1}.year^{-1}$, that is, a reduction of 11.9%. In the other selection situation, in monoclones, the average of the CC formed from size 5 (69.2 $m^3.ha$ $1.year^{1}$) and from size 20 (60.02 $m^3.ha^{-1}.year^{1}$) showed reduction of 13.3% (Table 2). It should also be highlighted that the mean of the composites, regardless of the size, was always superior when selection was made in the STP experiment. However, the superiority, although of small magnitude, grew with the increase in the number of clones in the composite: 1.03% in the composite with 5 clones to 5.1% in that of size 20.

An expressive result is the mean of the clones in the STP experiment, which, regardless of its size, was always greater than the corresponding mean if a CC was obtained from the monoclonal experiment. With size 5, the selection in the STP had a mean of 71.57 $m^3.ha^{1}.year^{1}$, and in the monoclone, of 56.46 $m^3.ha^{-1}.year^{1}$, which is quite an expressive difference (Table 2). An important finding, which was also expected, is that in no situation was the mean of the CC superior to the mean of all the clones considered individually. For example, in size 5 of the STP, the mean of the CC was lower, in the absolute value obtained, than clones 7, 2, and 11. However, if the response of the same clones is considered in the monoclone experiment, none of the five clones, if grown in isolation, would have a mean superior to the CC (Table 2).

It is noteworthy that with the increase in the number of clones in the composite, the number of clones with individual performance superior to the monoclones declines proportionally. Using selection in the STP of size 5, as already mentioned, 3 clones in 5 (60%) have a mean superior to the CC; and with 20 clones in the CC, this number goes to 8 in 20 (40%).

Parameters that evaluate adaptability or stability were estimated, considering different methodologies, size of the clonal composites, and also if selection was performed in the STP or MC in the experiment (Table 3). In other words, for each experiment, a means table similar to Table 2 was constructed. In the article, the tables with the composites of size 5 were presented, with selection from the STP and monoclone experiment. With the increase in the number of clones in the composite, the same trend that was commented on in the CC of size 5 is observed (data not shown). It was found the composite to be responsible for the occurrence

of the GE interaction – the greatest ecovalence estimate, however, was associated with the high mean. It should also be highlighted that the clone that had the lowest contribution to the interaction was 24, with an ecovalence estimate of 8%. However, it was associated with a lower mean.

The estimates of the reliability index (IC) of Annicchiarico (1992) draw attention. Note that the only IC higher than 100% was that of the CC. In other words, the CC was the only one of the treatments that, in the worst-case scenario, with 75% probability, would not have performance below the overall mean in any of the environments. All the monoclones would have a chance of having performance below the mean in some of the environments tested.

A noteworthy fact is that the estimates of IC showed the same trend with the increase in the number of clones. Only the clone of the highest mean (monoclone 7) in the CC of size greater than 5 did not show any estimate of IC lower than 100%, and the value increased with the increase in the number of clones in the composite. This occurred because, with the increase in the number of treatments evaluated, the overall mean of the environment declines and, that way, monoclone 7 is also expected, similar to the composite, which did not obtain performance below the mean in any of the environments.

When the selection was performed considering the monoclonal experiments, this same pattern of results is repeated. Considering the CC containing 5 clones, the greater contribution of the composite in the ecovalence estimates is evident, and also that the IC estimates greater than 100% only occurred for the CC (Table 3). As the number of clones increases in the composite, the mean of the CC decreases and, consequently, its contribution to the interaction. Therefore, clearly, with more treatments (clones), the contribution of each one decreases.

The results of the estimates obtained by the methodology of Nunes et al. (2005) are also presented in Table 3 for the size 5 composites, with selection in the STP and MC. Note that for the size 5 composite, with selection in the STP, the CC had the highest mean Z. It would be worth emphasizing that since Z values can be negative or positive, a constant with a value of 2 was added so that all estimates of Z were positive. In this condition, the mean of the different environments, instead of zero, was equal to 2. Under this condition, the risk of adoption of CC was null (Ri% = 0). None

Table 2. Mean of the clones (MAI m^3.ha-1.year-1) obtained in the STP (CC) or monoclone (MC) experiments. Selection of the best clones with the STP or monoclones as a reference. Mean results of possible composites of size 5, 10, 15, or 20 clones.

	Selection based on the STP			Selection in the monoclone		
Size	**Clone**	**Mean CC[2]**	**Mean MC[2]**	**Clone**	**Mean CC**	**Mean MC**
	7	75.19	60.72	7	75.19	60.72
	2	73.34	52.29	11	72.43	57.23
5[1]	11	72.43	57.23	47	70.31	56.42
	47	70.31	56.41	24	66.61	55.67
	24	66.61	55.67	18	61.48	55.2
	CC	71.57	56.46	CC	69.2	57.04
	30	66.4	54.78	8	62.33	54.93
	21	65.14	47.06	59	64.08	54.87
10	59	64.08	54.87	30	66.4	54.78
	22	62.93	49.86	13	58.99	54
	8	62.33	54.93	20	60.21	53.24
	CC	67.87	54.38	CC	65.8	55.7
	18	61.48	55.2	25	47.5	53.13
	20	60.21	53.24	16	58.35	52.59
15	27	60.13	44.12	12	51.94	52.42
	13	58.99	54	14	49.77	52.37
	56	58.52	49.86	2	73.34	52.3
	CC	65.21	53.34	CC	62.59	54.65
	16	58.35	52.59	1	51.83	51.3
	4	57.96	50.7	4	57.96	50.7
20	55	56.57	45.49	36	48.44	50.22
	60	55.67	47	9	55.11	50.19
	9	55.11	50.19	6	48.26	50
	CC	63.08	52.31	CC	60.02	53.61

[1]The number of clones in the composite is cumulative, i.e., size 10 involves the first 5 and 5 others. Likewise, size 15 involves the 10 already mentioned and 5 new ones. [2]Mean of the clone selected in the STP and mean of the same clone in the monoculture experiment.

of the other clones evaluated showed this same condition. Even the monoclone with the greatest mean obtained performance below the overall mean in some environments. Consequently, its risk of adoption was not zero and was of high magnitude. Another important estimate in this case is the coefficient of variation (CV%) of the estimates of Z. Once more, the CC stood out, with the lower estimate of CV indicating greater stability of performance (Table 3).

The graph analysis of the method of Nunes et al. (2005) allows visualization of what was commented on from the estimates presented in Table 3. The graphs obtained from the size 5 composite with selection in the STP were presented as an example. In this case, six graphs are shown: 5 of the monoclones and of the CC (Figure 1). In the figure, the red line represents the constant that was added to the standardized value. The black line represents the estimate of Z in each one of the environments evaluated, represented by letters from A to F. The only treatment that exhibited a "rounded ball" response was the CC, i.e., null risk. This standard is repeated for the other sizes of composites, except for the size 15 and size 20 composites, with selection in the monoclones, in which the risk of recommendation of the CC was not zero. However, under this condition, none of the monoclones evaluated had a Ri (%) equal to zero

Table 3. Overall mean of the MAI (m^3.ha-1.year-1), ecovalence parameter estimates (Wi^2)*, reliability index (Ii)**, coefficient of variation (CV%), mean Z***, and risk (%) of recommendation (Ri) obtained in evaluation of five clones and the clonal composite. Clones were selected from the STP experiment and monoclones, respectively, and the data of the monoclones were obtained in the monoclonal experiment.

Selection based on the STP						
Clone	**Mean**	**Wi^2**	**Ii**	**CV (%)**	**Mean Z**	**Ri (%)**
7	60.72	10.13	96.5	29	2.25	41.91
2	52.29	16.8	82.78	53	1.33	46.83
11	57.23	16.63	89.06	58	1.77	40.5
47	56.41	11.49	90.09	41	1.78	29.66
24	55.67	8	88.24	35	1.62	58.5
CC	71.57	36.92	110.68	19	3.26	0
Selection in the monoclone						
7	60.72	10.66	95.89	34	2.21	39.16
11	57.23	18.81	89.35	46	1.84	45.08
47	56.41	16.35	89.15	48	1.76	27.41
24	55.67	11.82	87.09	44	1.59	33.91
18	55.21	20.02	87.04	57	1.44	33.91
CC	69.2	22.31	108.69	22	3.16	0

*Methodology of Wricke. E (1964). **Methodology of Annicchiarico (1992). ***Methodology of Nunes et al. (2005).

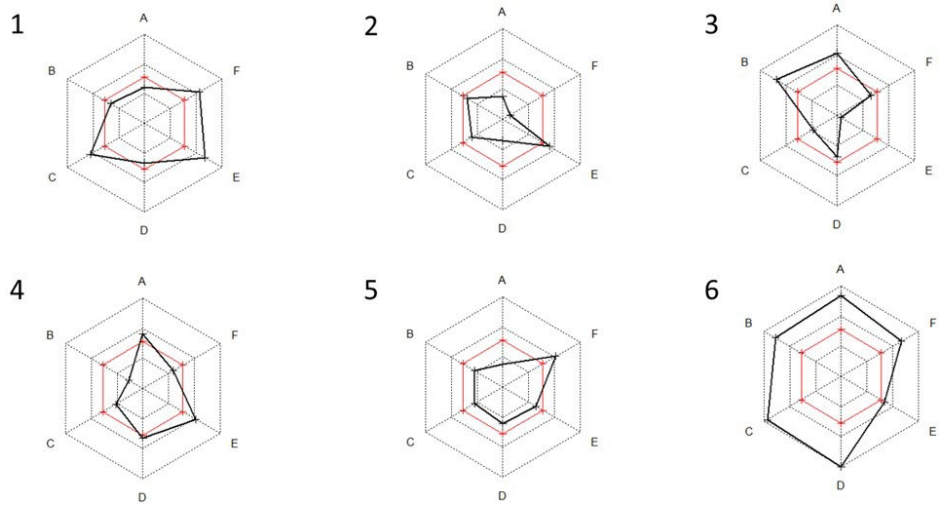

Figure 1. "Graphs generated for the clones and the clonal composite by the methodology of Nunes et al. (2005). The clones one to five represent the monoclones, and six, the CC, with selection in the STP experiment. The letters from A to F represent the environments. The red line represents the overall average with the addition of the constant to avoid the occurrence of negative estimates."

DISCUSSION

It is not easy to evaluate the performance of the clonal composites in relation to monoclones. This is because it is practically impossible to place CC and MC in a single experiment when evaluating a large number of clones, as was carried out by Martins et al. (2014). In this case, as the number of clones was large, the option was to conduct two contiguous experiments for evaluation of the same 60 clones, one in single tree plots (STP) and another with plots of monoclonal plants. As the accuracies of the experiments in each one of the six locations were high and very similar for the STP and monoclones, it can be inferred that the experimental accuracy was similar (Rezende et al., 2019).

The first positive fact is that the selections made in monoclones or in the clonal composite showed very similar results. This is a favorable condition because companies conduct initial evaluation of the clones in the STP and can use this recommendation to make composites or use it for recommendation of monoclones, which is already frequently done. A fact that also confirms this result is that the mean performance of the clones, though it showed variation among the locations, was very high (r = 0.85) in the mean of the various environments. Unfortunately, no report was found in the literature in which this information was obtained in the manner in which this study was conducted. However, there are reports that STP experiments classify the clones in a similar way to monoclonal experiments (Andrade et al., 2006).

In experiments for evaluation of clones in the forest area, the STP is frequently used (Nunes et al., 2018; Rezende et al., 2019; Santos et al., 2021)phenotypically similar and unrelated clones may be an important strategy to help breeders prevent commercial eucalypt plantations from unpredictable future adverse events, as well as to promote sustainable productivity gains. The present study was conducted to test this hypothesis by comparing the growth (MAI. However, some critics, not breeders, argue that the plants that neighbor a determined clone can affect its performance in a positive or negative way. Nevertheless, taking this experiment with 60 clones as an example, there is a large possibility that each clone has all the other treatments as a neighbor, exactly due to the large number of replications. Thus, each clone would have 240 (8 × 30) possibilities of having any one of the others as neighbors. A study conducted by Santos et al. (2021) using this same dataset showed that the estimate of regression between the response of a certain clone and its neighbors in the 30 replications was null, that is, no effect of the mean of the neighbors was found on the performance of the different clones present in the STP.

The six assessment sites represent most of the company's areas planted with eucalyptus. These environments differ in altitude, topography, soil fertility and, clearly, climatic conditions (Table 1). The average productivity of each site was very different, reflecting this environmental variation. What is expected is that this variation can explain what happens in the future. If this occurs, the inferences to be made will be coherent. This fact, associated with the great genetic variation observed among the clones, allowed the clones x environments interaction to be expressive. This condition is essential to achieve the objectives of this study.

The ecovalence estimates (W^2) for the clonal composite were nearly always higher than those for most of the monoclones (Table 3). The W^2 estimates the percentage contribution of a determined genotype/clone to the interaction (Wricke, 1994). The fact that the estimates of the CC were most of the time greater than those of the monoclones implies that their contribution to the interaction was large. Theoretically, it could be argued that this is an unfavorable situation. Nevertheless, a more detailed analysis of the results reveals that this is a situation in which the interaction is very favorable for the breeder. That is because most of the monoclones had a mean value below the CC, regardless of its size (Table 2). Thus, the CC took better advantage of the environmental stimulus than the monoclones involved, which is the expectation in seeking to take advantage of the more favorable environmental differences. This fact collaborated so that its contribution to the interaction was greater. According to Becker (1988), ecovalence measures agronomic stability, that is, the behavior of the genotype accompanies the mean of the environment, and, therefore, if a determined genotype/clone responds better than the others to the environmental stimulus, so their contribution to the interaction was large, and goes in the direction that the breeder want.

Obviously, breeders are unable to predict what will happen in the future, especially in growing perennial plants, in the years following recommendation of a clone, for example. When evaluation of the clones is performed in various environments, it is expected that the different environmental conditions can well represent what is expected for the coming years. If that occurs, the estimate of the reliability index (I*i*), which estimates the risk in choosing a determined genotype (Annichiarico, 1992), is fundamental for breeders. The estimates of I*i* for the CC were all superior to 100%, regardless of the size of the composite formed. At the same time, most of the monoclones that constituted the respective composite exhibited (I*i*) lower than 100% (Table 3).

A similar result was indicated by the methodology of Nunes el al. (2005). The clonal composite exhibited zero risk of recommendation in practically all the opportunities, because there was no estimate lower than the mean of the standard value (Z) in any of the environments evaluated, except when the selection occurred in the monoclones with CC of sizes 15 and 20 (data not shown). Clearly, with many clones in the composite, it is probable that good and bad clones are involved. As these same clones form the composite, it is possible that in determined environments some CCs may exhibit performance below the standardized mean. This methodology allows a graph-based analysis that makes it possible to didactically visualize what occurs in the response of the CC and compare it with the monoclones individually. The graph shapes are known as a "rounded ball" or "flat ball" due to the format generated when a clone is above the mean (Z) in all the environments, or below the mean (Z) in some environments. In practically all situations, the composites exhibited a "rounded ball" response.

As already mentioned, the clones with low performance in the future should be removed in the next plantings, an operation called "purification" of the composite. With ten clones in the CC, the elimination of one of them still leaves the composite with a good number of clones. Another fact that should be widely exploited with the use of CC is that the performance of each clone can be observed in the different growing regions. If some of these clones stand out, they can later be recommended as monoclones. In this new situation, there is greater possibility of success, due to expansion of the environments in which they were evaluated.

CONCLUSIONS

The manner of identifying the clones that will constitute the composite does not depend on whether they come from monoclonal experiments or from the STP. In many situations, the contribution of the clonal composite to the interaction was high. However, this contribution was always associated with high wood yield, indicating that the clonal composites took better advantage of the differences in the environmental stimuli (of the different locations) than most of the monoclones that entered into their composition. The estimates of risk in recommendation of the clonal composites were, in most situations, lower than the estimates of risk in recommendation of the different monoclones. In summary, use of the clonal composite proved to be more efficient than that of monoclones in mitigating the effects of the clones × environments interaction.

AUTHORSHIP CONTRIBUTION

Project Idea: OAFC, LJL, NE, RMAP
Database: OAFC, LJL, CVQ, RMAP
Processing: OAFC, LJL, CVQ, RMAP
Analysis: OAFC, LJL, NE, CVQ, RMAP
Writing: OAFC, LJL, NE, CVQ, RMAP
Review: OAFC, LJL, NE, CVQ, RMAP

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