# Necessity of the inclusion of borders in value of cultivation and use trials in upland rice

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## Abstract

Experimental accuracy in crop research is directly affected by the size of plots. For this reason, researchers use empirical knowledge to determine plot size. There are also other important aspects for determining ideal plot size. These include the type of crop and the use, or not, of borders. The objective of this research was to verify the necessity of including border material in the value of cultivation and use trials in breeding programs of upland rice and to evaluate the experimental accuracy with and without the inclusion of borders. The research was conducted in an experimental area at the Federal University of Lavras, located in the State of Minas Gerais, during three harvests (2014/2015, 2015/2016, 2016/2017). Thirteen upland rice strains and methods of evaluation (useful area and border) were evaluated. A randomized complete block design with three replications was used to evaluate grain yield. Individual analyses of variance were performed considering the useful areas and the borders for the three agricultural years. A joint analysis was also performed with the use of a subdivided plot involving the location of the harvest in terms of the useful area and border among the rice strains. It was concluded it is necessary to use borders in the value of cultivation and use trials in breeding programs of upland rice as it contributes to the performance and experimental accuracy of research results.

**Keywords:** *Oryza sativa.* Yield. Experimental planning.

## Introduction

Rice (*Oryza sativa*) is considered one of the main foods for the majority of the world's population, especially in developing countries such as Brazil. It is a high energy cereal due to the concentration of starch, besides supplying vitamins and minerals.

With population increases and growing demand for food, agricultural production–will need to double over the next 20 years (FRANKARD et al., 2011). One of the great challenges of modern ag-

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riculture is thus to expand and assure crop production in the face of climate change (CECCARELLI, 2010). Rice is seen as being of extreme importance and having the greatest potential for increasing the fight against world hunger (GOMES et al., 2004).

The rice crop in Brazil is grown in two production systems: lowland and upland. The upland system can be either a traditional dryland system or a dryland system under supplemental irrigation. The dryland system predominates and is mainly characterized by the use of low technology, high risk, low yield and low production costs (GUIMARAES; MEDEIROS; SOARES, 2005). According to CONAB (2017), the area producing upland rice in 2016/17 was 26.09% of the national production area and that of irrigated rice equivalent to 73.91%. The average yields were 2.28 ton $ha^{-1}$ and 7.50 ton $ha^{-1}$ respectively.

Although it is a very important crop for the economy and the world, there is comparatively little research and biotechnological development in rice. The present research is mainly aimed at the breeding of grain for the upland system. Rice prevails as a clearing crop to recover degraded areas or to prepare the soil for cultivation of soybeans or maize.

Concerning breeding programs in Brazil before strains or cultivars are released to producers, phenotypic performance evaluations, under different edaphoclimatic conditions, are required for at least two harvests. These 'value of cultivation and use' trials establish how the cultivars can be grouped together according to the period of vegetative development. The experiments are conducted using a randomized block design (RDB) with three replications, composed of five rows of five meters in length, and a distance between rows of forty centimeters. The useful area (4.8 $m^2$), therefore, is formed by the three central rows.

To determine the appropriate size of a plot for a species and under certain conditions, several factors must be considered. These include the level of acceptable experimental error, the variability of individual plants within the plot in relation to the variability among plots, the experimental design, the agronomic characters being evaluated, the growth characteristics of the crop, the cost per individual plant in relation to the cost per experimental unit and mainly the soil heterogeneity (PORTMAN; KETATA, 1997; ANDRADE, 2002; ALVES; SERAPHIN, 2004).

The border effect measures the difference in yield between the central and border rows of a plot. Thus, the border is important to avoid the influence of adjacent experimental units, in order to reduce the effects of competition between plots of different trials and, consequently, the experimental error (STORCK, 2005).

The use of very large plots generates increased possibility of homogeneous blocks. When plots are small, they can be influenced by adjacent plots, besides the differences among plants or missing plants within plots.

Experimental accuracy is thus directly affected by the size of the plot, which is why researchers choose empirical knowledge for determining size. There are also other important aspects for the determination of ideal plot size. These include type of crop and the presence or absence of border.

Valentini (1988) emphasizes the use of borders obviously increases the plot size as well as the maintenance costs. Larger plots require more cropping supplies and also the realization of more farming practices. Therefore, the use of border is only recommended when there is an effect on experimental precision in terms of competition among plots. Otherwise, according to Storck et al. (2005), the researcher can collect data from the entire experimental unit, permitting the use of smaller experimental areas, and a larger number of replications in the same experimental area. This may result in greater experimental precision.

Studies performed with different species have shown different results regarding the necessity to use the borders. In bean crops, in some cases it has been shown that the use of borders has contributed to improved experimental accuracy (DEBOUCK; HIDALGO, 1985; COSTA; ZIMMERMANN, 1998). Cargnelutti Filho (2003), however, in studies conducted with maize, concluded the use of borders did not modify the precision of the tests, inferring that smaller plots and data from only the useful area can produce experimental precision.

The border effect on the experimental accuracy of competitive tests in upland rice strains in Minas Gerais is unknown. Thus, the objective of this research was to verify the significance of using borders in the value of cultivation and use trials, in a breeding program of upland rice. A second objective was the determination of the experimental accuracy of the different forms of harvesting (with and without border material) of a plot.

## Material and methods

The research was conducted in an experimental area of the Agricultural Department of the Federal University of Lavras (UFLA), located in Lavras, Minas Gerais, at an altitude of 954 m, 21º12'11'' South latitude and 44º58'47'' West longitude. The climate is classified as subtropical humid. The average temperature is 19.4° C; the annual average rainfall is 1529.7 mm and the region has two well defined seasons: drought from April to September and wet season from October to March, Cwb type, according to the Köeppen climate classification (ANTUNES, 1986). The predominant soil in the experimental area is of the Latosol group, classified as typical dystroferric dark red latosol.

Thirteen upland rice strains, from the Value of Cultivation and Use (VCU) trials, of the Upland Rice Breeding Program from the Federal University of Lavras were selected in agreement with the Embrapa Rice and Beans and Epamig programs. The research was conducted during three harvests. The list of the strains is presented in Table 1.

**Table 1 –** Upland rice strains evaluated in the harvests of 2014/15, 2015/16, 2016/17.

| Identification | Genotypes |
|---|---|
| 1 | CMG 2162 |
| 2 | CMG 2168 |
| 3 | BRS Esmeralda |
| 4 | CMG 2170 |
| 5 | BRSMG Caçula |
| 6 | CMG 2185 |
| 7 | CMG 2187 |
| 8 | CMG 2188 |
| 9 | CMG 2085 |
| 10 | BRSMG Caravera |
| 11 | CMG 1511 |
| 12 | CMG 1896 |
| 13 | CMG 1509 |

**Source**: Elaborated by the authors (2019).

The VCU experiments were conducted based on the 2014/15, 2015/16 and 2016/17 harvests. The experimental design was a randomized complete block, with three replications. The experimental plots consisted of five rows, four meters in length, spaced 0.35 m, and with a sowing density of 80 seeds per linear meter. No-tillage was used and the management was similar to that adopted for commercial planting in the region, with irrigation at 80% of the field capacity applied on the crop by a sprinkler system. Channeling for planting and fertilization were done mechanically. At planting, 450 kg $ha^{-1}$ of 8-28-16 was applied. The sowing density was 80 seeds/linear meter. For weed control, the Herbadox herbicide was applied soon after planting, before the emergence of the rice plants. Then, 30 days after emergence, Clincher herbicide and Ally herbicide were applied. At the grain maturation, the useful area of the plot and the two side rows (borders) were harvested separately. The yield, in kg $ha^{-1}$, was evaluated.

Following data collection, individual and joint analyses of variance were performed (COX; COCHRAN, 1957) using the SISVAR statistical program (FERREIRA, 2011). Individual analyses of variance were conducted on the useful area and the border for the three harvests. A joint analysis (useful area and border) with the use of a subdivided plot was conducted among all of the strains to identify any significant differences among the plots (RAMALHO, 2005). Finally, a triple interaction analysis was performed to follow the behavior of the rice strains in terms of differences associated with positions in useful areas or on the border of the plots in the three harvests. Experimental precision was calculated using the coefficient of variation (CV) for the joint analysis of each agronomic character, evaluated individually (RESENDE; DUARTE, 2007).

## Results and discussion

The summary analysis of variance for yield (kg $ha^{-1}$) for each harvest, considering only the useful crop area and the border harvest is presented in Table 2. The experimental precision was evaluated by the coefficient of variation (CV%). It was considered high among all of the data except for the border in the harvest 2016/17. Analyzing only the coefficients of variation in all harvests, higher experimental accuracy was found when harvesting the useful area. This was to be expected since the main function of the border rows is to reduce the effects of treatments among plots. The average yields of the useful area in the three harvests were higher than the averages of the border.

Dias (2013) found similarity in the estimates of the coefficients of variation for the useful area and border, suggesting there are no significant differences in the degree of competition among plants in the two areas and that the uncontrollable environmental factors similarly influenced both areas. Significant differences were found among the rice strains examined. This result indicated the existence of genetic variability among them. It suggests possibilities for success in the selection of strains with different yields (kg $ha^{-1}$) according to the VCU trials.

**Table 2** – Individual analyses of variance for yield (kg $ha^{-1}$) considering the harvests of 2014/15, 2015/16 and 2016/17 and the averages obtained in the plots of useful area and border.

| Harvest | Plot | Strains | | Pr>F | Average | CV (%) |
|---|---|---|---|---|---|---|
| | | DF | AS | | | |
| 14/15 | Useful | 12 | 862361,9544 | 0,0017* | 4050,64 | 11,38 |
| | Border | 12 | 11508247,57 | 0,003* | 3692,55 | 13,76 |
| 15/16 | Useful | 12 | 1223124,153 | 0,0204* | 4773,14 | 14,24 |
| | Border | 12 | 1378812,099 | 0,1054ns | 4698,26 | 18,6 |
| 16/17 | Useful | 12 | 2993085,422 | 0 | 4132,09 | 15,53 |
| | Border | 12 | 2332561,949 | 0,012* | 3525,49 | 25,3 |

[*] - significant at 5%, [NS] - not significant

**Source**: Elaborated by the authors (2019).

The analysis of joint variance in yield (kg $ha^{-1}$) for the areas evaluated and the strains examined is presented in Table 3. The sources of variation (SV) were the border and useful area. The strains differed significantly with little coinciding behavior among the results of the strains according to the VCU during the three harvests. The source of variation areas presented significant F test results ($p \leq 0.05$), indicating the differences in plots influenced the yield of rice for the 2014/15 and 2016/17 harvests, although it was not significant for 2015/16. There was no significant interaction between strains *versus* plots in the 2014/15 and 2015/16 harvests, indicating the strains demonstrated coincident performances in the different plots, a fact suggesting there was no need to use border material for VCU evaluations.

**Table 3** – Analysis of joint variance for yield (kg $ha^{-1}$), considering the evaluated strains and plots (useful area and border) in each harvest, conducted in 2014/15, 2015/16 and 2016/17.

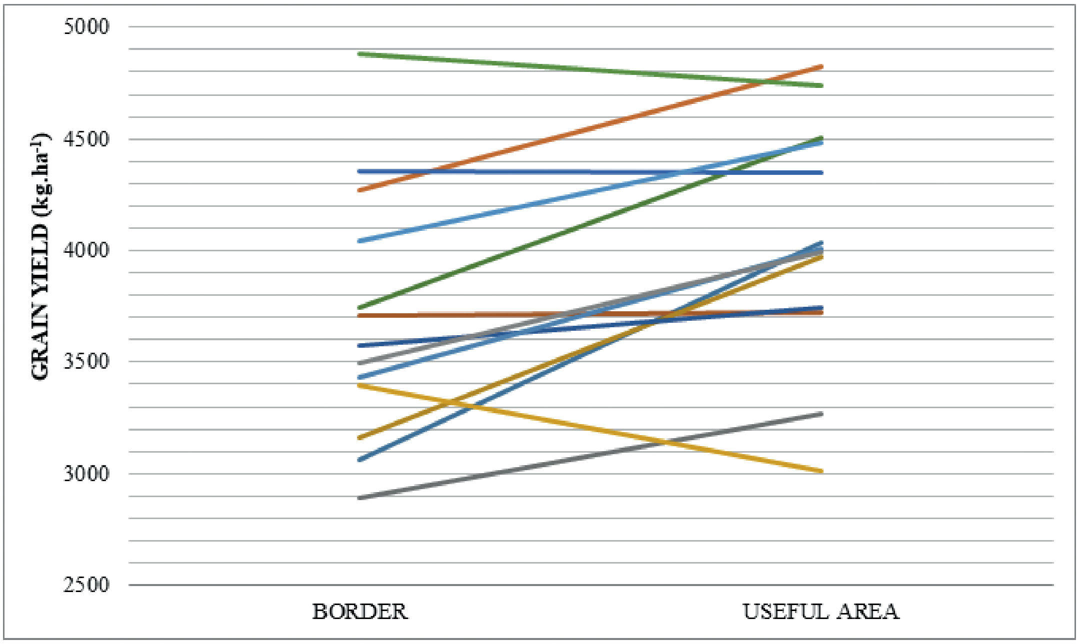
| SV | DF | AS | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2014/15 | | 2015/16 | | 2016/17 | |
| Replications | 2 | 3020378,931 | * | 2304059 | * | 170343 | ns |
| Strains | 12 | 1578372,797 | * | 2469652 | * | 4071367 | * |
| Strains*Replications | 24 | 344960,2022 | * | 1001961 | * | 870570,5 | * |
| Plots | 1 | 2500461,9 | * | 109330 | ns | 7175132 | * |
| Strains*Plots | 12 | 243009,7881 | ns | 132283,8 | ns | 1254281 | * |
| Error | 26 | 117140,1621 | | 241326,4 | | 325756,1 | |
| CV (%) | | 8,84 | | 10,37 | | 14,91 | |

* - significant at 5%, ns - not significant

**Source**: Elaborated by the authors (2019).

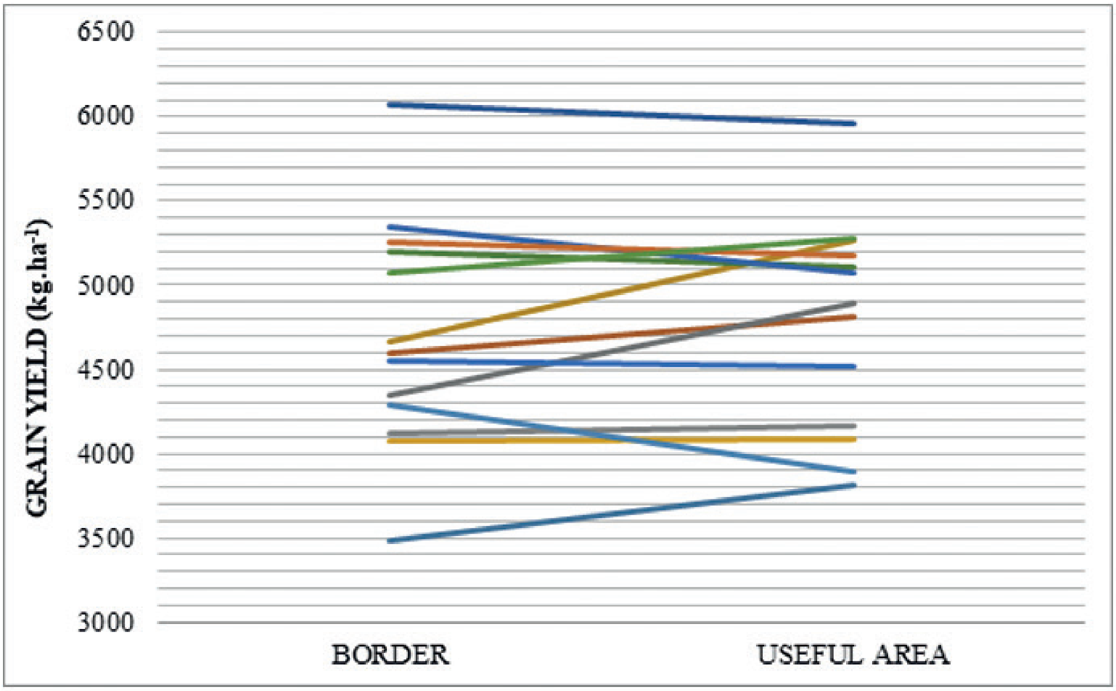
To visualize the results, graphs were plotted (FIGURES 1, 2 and 3) for each harvest in order to examine the yields as indicated by data from the useful area and the border. A significant interaction was noted in the 2016/17 harvest (FIGURE 3), according to Table 2. For the other harvests (2014/15 and 2015/16), differences were less notable between the useful area and the border, justifying the non-significance of the interaction, strains *versus* plots of Table 3.

**Figure 1** – Comparative graph on the performance of yield lines (kg.ha-1) in relation to the 2014/15 useful area and crop border rows.



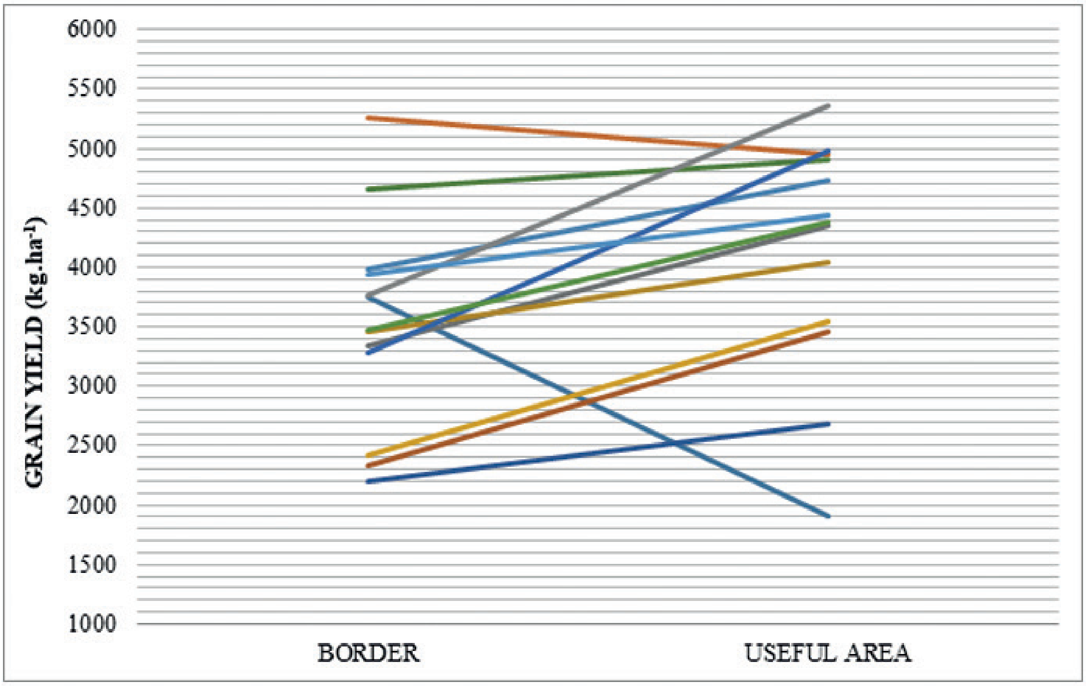

**Source**: Elaborated by the authors (2019).

**Figure 2** – Comparative graph on the performance of yield lines (kg.ha-1) in relation to the 2015/16 useful area and crop border rows.




**Source**: Elaborated by the authors (2019).

**Figure 3** – Comparative graph on the performance of yield lines (kg.ha-1) in relation to the 2016/17 useful area and crop border rows.




**Source**: From the authors (2019).

The analysis of triple joint variance for the three harvests is shown in Table 4. The plots that demonstrated variation showed significant results during the three agricultural years. When the sources of variation were examined, it was determined the inclusion of borders was important. This is explained by the fact that the average yield obtained in the useful areas was statistically higher than that from the border (TABLE 5). It is also noted that there was an interaction between plots *versus* harvest, indicating that different agricultural years may influence the differences in useful area and border data. Allard and Bradshaw (1964) justify this result explaining there are predictable and unpredictable aspects that contribute to the interaction of strains with the environments to which they are submitted. Environmental variations that occur from place to place such as climate, soil and agronomic techniques are predictable. Annual variations in rainfall distribution, soil, air temperature, and frost occurrence, however, cannot be predicted.

**Table 4** – Analysis of triple joint variance for yield (kg $ha^{-1}$) considering the evaluated strains, useful area and border material collected and each harvest (2014/15, 2015/16 and 2016/17).

| SV | DF | AS |
|---|---|---|
| Harvest | 2 | 20422752* |
| Rep(Harvest) | 6 | 1831594* |
| Strains | 12 | 4301665* |
| Strains*Rep(Harvest) | 72 | 739164* |
| Strains*Harvest | 24 | 1908864* |
| Plots | 1 | 7024473* |
| Plots*Harvest | 2 | 1380225* |

| SV | DF | AS |
|---|---|---|
| Plots*Strains | 12 | 338870$^{ns}$ |
| Plots*Strains*Harvest | 24 | 645352,1* |
| Error | 78 | 228074,2 |
| CV | 11,52% | |

* - significant at 5%, $^{ns}$ - not significant

**Source**: Elaborated by the authors (2019).

The non-significance of the source of variation between strains *versus* plots (useful area and border) allows us to infer the behavior of strains in relation to the areas of data collected did not vary for the harvests. However, as previously reported in the individual analysis (TABLE 2), there was higher experimental accuracy in the useful areas, justifying the use of borders contributes to a better performance of the strains.

Finally, when considering the triple interaction: plots (useful area and border) *versus* strains *versus* harvest, there was a significant F test (P≤0.05), which allows us to conclude that in different years of harvests there were different results in terms of significance of using borders, as manifested by all of the strains.

**Table 5** – Test of strain averages in yield (kg ha$^{-1}$) between the useful areas and borders for the three harvests.

| Plots | Averages | Test |
|---|---|---|
| Useful area | 4318,62 | a |
| Border | 3972,10 | b |

Means followed by the same letter do not differ statistically with a level of 5% by the Scott & Knott grouping test.

**Source**: Elaborated by the authors (2019).

Table 5 indicates there is justification for the use of borders in the VCU trials for upland rice. Krause et al. (2007) concluded the use of borders in common bean research did not contribute to the improvement of experimental accuracy and did not change the average performance of the evaluated lines. Higher experimental accuracy was obtained when considering only the total area of the plot. In contrast, Oliveira (2005) highlights that replacing the borders with a larger number of repetitions is not recommended for comparing experiments of hybrid maize.

Experiments associated with the use of borders have produced varying results. In irrigated rice, for example, it was evidenced the use of borders in yield evaluation tests is indispensable. Other research has recommended the quantity of border material used in yield trials should not be the same for cultivars with different agronomic characteristics, emphasizing the necessity for additional research on the subject (VERNETTI et al., 1982). In upland rice crop research, Zimmermann (1980) recommended the use of two rows of border in order to obtain greater experimental accuracy.

According to Marques Junior (1997), the use of border in bean research did not provide significant improvements in the efficient evaluation of segregated populations, for this reason, its use was not recommended for bean research.

Since the use or lack of border did not alter the accuracy of the cultivars in bean tests, it can be inferred the use of smaller plots using only the useful area would maintain the same accuracy. Thus, the use of more replications in the same experimental area has been recommended, obtaining more statistically significant results (RIBEIRO et al., 2001). Similarly, in yield studies for maize, the elimination of borders for comparing cultivars did not alter the accuracy of the experiment (CARGNELUTTI FILHO, 2003).

## Conclusion

It was concluded it is necessary to use borders in the value of cultivation and use trials in breeding programs of upland rice as it contributes to enrich the performance and experimental accuracy of the information gathered from the useful areas of the plots.

## Necessidade de bordadura em ensaios de valor de cultivo e uso na cultura do arroz

### Resumo

A precisão experimental é afetada diretamente pelo tamanho da parcela e, por esse motivo, os pesquisadores adotam conhecimentos empíricos para o seu dimensionamento. Além disso, há outros importantes aspectos para a determinação do tamanho ideal da parcela como tipo de cultura e presença ou ausência de bordadura. Portanto o objetivo deste trabalho foi verificar a necessidade da utilização de bordaduras nos ensaios de Valor de Cultivo e Uso em um Programa de Melhoramento de Arroz de Terras Altas e avaliar a precisão experimental na presença ou ausência de bordadura. O estudo foi conduzido em área experimental na Universidade Federal de Lavras, localizada na cidade de Lavras, Minas Gerais, durante três safras (2014/2015, 2015/2016, 2016/2017). Foram avaliadas linhagens de arroz de terras altas e seus diferentes tipos de colheita (área útil e bordadura). O delineamento realizado foi de blocos casualisados, com três repetições, avaliando a produtividade de grãos. As análises de variância individuais foram realizadas considerando somente a área útil e a bordadura para os três anos agrícolas. Procedeu-se também à análise conjunta com emprego de parcela subdividida no espaço envolvendo a posição da colheita da área útil e bordadura, além das linhagens. Pode-se concluir que se faz necessária a utilização de bordaduras em ensaios de Valor de Cultivo e Uso em Programas de Melhoramento de Arroz de Terras Altas, por contribuir para a melhoria do desempenho e precisão experimental das linhas centrais das parcelas.
**Palavras-chave:** *Oryza sativa.* Produtividade de grãos. Planejamento experimental

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