



RESEARCH ARTICLE

SELECTION FOR MULTIPLE TRAITS IN UPLAND RICE PROGENIES USING THE Z INDEX

Danielle Coutinho Ribeiro, Isabela Pereira de Lima, Marcela Pedroso Mendes, Heloisa Oliveira dos Santos, Cíntia Souza Rodrigues, *Flávia Barbosa Silva Botelho, Luiz Eduardo Bertolo, Felipe Pierobon, Gabriele Carvalho, Moizés de Souza Reis and Natalia Botega Alves

Department of Agriculture, Federal University of Lavras, P.O. Box 3037, 37200-000, Lavras, Minas Gerais, Brazil

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ABSTRACT

Rice research institutions have been dedicated to solve problems related to increasing grain yield and enhance the performance of rice lines for important agronomic qualitative traits. However, breeding for multiple traits is difficult since traits frequently show a not always positive phenotypic correlation between each other. Among all alternatives to deal with multiple traits, index selection is expected to be the most efficient and the easier choice in many crops. Therefore, the aim of this study was to select upland rice progenies for important agronomic traits simultaneously using the Z index approach. Genotypes from the Upland Rice Breeding Program from the Federal University of Lavras, MG, Brazil were evaluated for plant height, number of days to flowering, neck blast resistance, leaf blast resistance, grain discoloration resistance, brown spot resistance, and leaf scald resistance using a simple square lattice 14x14 design comprising of 192 progenies F_{2:4} and four commercial upland rice cultivars. The Z index was obtained per plot from the sum of the standardized values of the six traits, except plant height, and the genotypes means of Z were compared according to the Scott-Knott approach. The phenotypic selection was performed first for plant height, and then considering the Z index. Of the 196 progenies, 96 were selected for plant height, and of these, 60 were selected for the Z index, corresponding of a selection intensity of 30%. The progenies that stood out considering the traits separately also showed the best index, indicating that the Z index was efficient in selecting upland rice genotypes for multiple traits simultaneously.

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INTRODUCTION

Rice (*Oryza sativa*) is a grass from the genus *Oryza* and the second most consumed cereal in the world (Guimarães et al., 2006). Brazil is the main producer of rice outside Asia, producing about 12.39 million of tons of grains in the 2014/2015 growing season. However, projections of the planted area point to a significant reduction in the coming years, especially of upland rice, which the harvest in the 2014/2015 season decreased 1.2% compared to 2013/2014 growing season. This fact is rather disturbing since the consumption tends to increase significantly in the next few years. For many years, rice research institutions in Brazil have been dedicated to solve problems related to increasing grain yield and enhance

the performance of rice lines for important agronomic qualitative traits. However, many regions with great productive and market potential are not farmed due to the absence of rice cultivars best suited to specific environments. In this sense, upland rice plays a strategic role enabling rice cropping in regions where is not possible to flood. In the 60's, upland rice had an important part during the occupation of new agricultural areas in the Brazilian west region known as "cerrado". This occupation had its peak in the period between 1975 and 1985, when upland rice farming reached more than 4.5 millions ha. However, in the last few years upland rice cultivation dropped due to the competition with other crops and to the absence of new modern cultivars. To release a new cultivar, it must have a higher performance than the current cultivars in the market, so plant breeders need to evaluate the progenies for multiple traits (Ramalho et al., 2012). In upland rice breeding programs, besides grain yield, agronomic traits as precocity, plant height, grain quality, and pathogen resistance

*Corresponding author: Flávia Barbosa Silva Botelho
Department of Agriculture, Federal University of Lavras, P.O. Box 3037, 37200-000, Lavras, Minas Gerais, Brazil

are the main traits considered in the selection. However, breeding for multiple traits is generally more difficult than breeding for a single-trait alone due to the phenotypic correlation that traits frequently show (Bernardo, 2010). The index selection involves selecting for several traits simultaneously on the basis of a single index value (Bernardo, 2010; Falconer and Mackay, 1996). It is usually a linear combination of the different traits and accounts for the relative superiority of progenies for all traits included in the index (Bernardo, 2010). Among all alternatives to deal with multiple traits, index selection is expected to be the most efficient and the easier choice in many crops (Bernardo, 2010; Hazel and Lush, 1942; Missio et al., 2004; Vieira et al., 2005; Smiderle, 2015). Mendes et al. (2009) proposed the Z index, obtained from the standardization of the data from each character per plot, allowing a statistical inference about the indices values associated to the progenies (Ramalho et al., 2012). Despite its easy application, no reports were found in upland rice breeding. Therefore, the aim of this study was to select upland rice progenies simultaneously for plant height, number of days to flowering, neck blast resistance, leaf blast resistance, grain discoloration resistance, brown spot resistance, and leaf scald resistance using the Z index approach in order to guide the recommendation of new cultivars to the state of Minas Gerais-Brazil.

MATERIAL AND METHODS

Genotypes from the Upland Rice Breeding Program from UFLA were evaluated for (i) plant height (cm), taken from the ground to the tip of the main panicle; (ii) number of days to flowering, taken from sowing to when 50% of the plants of each plot showed panicle; (iii) neck blast resistance, caused by the fungus *Magnaportheorizae*; (iv) leaf blast resistance, also caused by the fungus *Magnaportheorizae*; (v) grain discoloration resistance, caused by a complex of multiple fungus and bacteria; (vi) brown spot resistance, caused by the fungus *Bipolarisoryzae*; and (vii) leaf scald resistance, caused by the fungus *Microdochiumorizae*. All diseases were evaluated using a grading scale from 1 to 9, which 1 means no symptom and 9 means that all plot showed severe symptoms. The experiment was carried out in the 2014/2015 growing season at the experimental field of the Agriculture Department of UFLA in Lavras-MG, Brazil (21°14'43"S, 44°59'59"W). It was used a simple square lattice 14x14 design with 196 rice genotypes comprising of 192 progenies F_{2.4} and four commercial upland rice cultivars as checks. Plots consisted of two rows of 3 m spaced 35 cm with 80 seeds per meter. All cultivation practices necessary for the development of the crop were performed according to the technical recommendation for the environment, except that no fungicide was used because disease tolerance was part of the evaluation.

Selection index

First, it was performed the standardization (also called z transformation) of the data from each character, except plant height, according to:

$$z_{ijk} = \frac{y_{ijk} - \bar{y}_{jk}}{s_{jk}}$$

where z_{ijk} was the standardized value of the plot containing the genotype i of the block j of the character k ; y_{ijk} was the phenotypic value of the plot containing the genotype i of the block j of the character k ; \bar{y}_{jk} was the phenotypic mean of the block j of the character k ; and s_{jk} was the phenotypic standard deviation of the block j of the character k . Therefore, it was obtained a z value for each plot in each character. The selection Z index was obtained per plot (z_{ij}) from the sum of the standardized values of the six characters (Ramalho et al., 2012):

$$z_{ij} = \sum_{k=1}^6 z_{ijk} = z_{ij1} + z_{ij2} + \dots + z_{ij6}$$

Analysis of variance was performed with the z_{ij} index following the lattice design and using the statistical software R (R Development Core Team, 2012). The adjusted means were compared according to the Scott-Knott approach (Scott and Knott, 1974) with 5% of probability. The phenotypic selection was first performed considering the data from plant height. This trait was not accounted in the Z index because the ideal phenotype for plant height is intermediate. Therefore, before performing the selection using the Z index, it was selected genotypes with height between 95 cm and 105 cm. After selecting for plant height, it was used the Z index to perform the selection for the other six traits simultaneously. The desired phenotypes were the ones with lower scores of diseases and less number of days to flowering, so there were selected genotypes with low Z index distinguished by the Scott-Knott test. The phenotypic selection using both plant height data and Z index had an intensity of 30%.

RESULTS AND DISCUSSION

Highly significant differences ($p \leq 0.05$) between genotypes were detected in the analyses of variance for all characters: plant height, number of days to flowering, neck blast resistance, leaf blast resistance, grain discoloration resistance, brown spot resistance and leaf scald resistance (not shown). This result suggests existence of the genetic variability between progenies necessary to achieve gain with selection. Also high accuracy estimates were observed for all characters ($r > 0.70$), indicating that the experiment was carried out with good precision (Resende and Duarte, 2007). Lin et al. (2011) discuss that plant height and number of days to flowering are detrimental in rice domestication and in modern breeding programs. Plant height plays an important role in grain yield improvement since genotypes with reduced height can avoid wind and rain damage for resistance to lodging and for increase yield with adequate fertilization by nitrogen. Precocity, in its turn, is one of the most important traits related to rice adaptation in multiple regions and cropping seasons. Neck and leaf blast are caused by the fungus *Magnaportheorizae* and are the most destructive diseases of rice. Because neck blast affects the panicle directly, yield losses in affected plants are very high. According to the International Rice Research Institute (IRRI, 2015), blast can occur in areas with low soil moisture, and with frequent and prolonged periods of rain shower. In upland rice, a large day-

night temperature difference greatly favors the development of the disease. This is a very common environmental condition in most states of Brazil and it is extremely important the obtaining of upland rice lines with blast resistance by Brazilian rice breeding programs.

Table 1. Height (cm) and Z values of the 60 upland rice progenies selected

Progeny	Height	Z Value	Progeny	Height	Z Value
5	104,25	-1,0814	92	98,5	-2,0457
9	103	-0,9498	93	100,75	-3,3735
11	95,25	0,3756	96	98,75	-1,8084
12	102,25	-1,6236	97	104,25	-1,7959
14	100,75	-1,4398	98	102,5	-2,4679
15	100,25	-1,9734	106	101,5	-0,3249
17	96,25	-2,8384	107	101,25	-1,9518
18	98,75	-2,3597	110	99,5	-1,7162
19	102,5	-1,2318	114	95,5	-0,8586
20	100,5	-0,8275	119	96,25	-2,6841
24	101,75	-3,804	120	97,5	-2,7657
26	98,25	-0,2814	122	100,25	-1,1482
27	100,5	-0,4466	125	98,75	0,1905
30	104,75	0,0997	127	104,25	-3,5794
33	103,75	-1,0458	129	104,75	-1,8106
39	102,5	-2,5157	130	96,25	-0,7772
44	103	0,4322	134	99,75	-2,647
45	102,75	-0,784	135	95,75	-2,1303
47	100,5	-0,805	136	104	-1,7681
49	101,5	0,353	142	100	-5,2984
54	103,75	-0,6165	147	97	-1,1145
61	96,5	-2,6861	150	101,5	-0,3121
67	95,75	-3,4936	153	102,25	0,1255
69	99,75	-0,7702	154	95,5	-1,3116
73	102,5	-0,6159	156	102,25	-0,3001
85	105	-3,1719	173	104,5	-2,0152
87	104,5	-1,5479	180	104,5	0,2887
88	98,25	-2,8819	186	103,75	-1,2279
89	97,25	-4,139	187	98	-0,2714
90	98	-4,1063	196	98,5	-0,1116

nitrogen fertilization and close spacing, showing a scalded appearance of leaves. Although brown spot also affect coleoptile, leaf sheath, panicle branches, glumes and spikelet, its major damage are the big spots on the leaves, which can kill the whole leaf and cause as high as 45% yield loss. Grain discoloration drastically reduces the market value of rice since whiteness is an important quality characteristic for rice consumers.

It occurs due to microorganisms and fungus that grow around the germ end of the brown rice kernel, causing black spots (IRRI, 2015). All management options available should be used to deal with these diseases, including monitor soil fertility regularly, use fungicides, and keep rice grains in proper drying and storage conditions. However, for all diseases evaluated in this study, one of the most efficient and economical management for the farmer is to use resistant lines. Of the 196 progenies, 96 showed ideal plant height values, with means between 95 cm and 105 cm, consisting the first step of selection. After selecting for plant height, it was used the Z index to perform the selection for the other six traits simultaneously. Of the 96 progenies selected for plant height, 60 showed low values for the Z index distinguished by the Scott-Knott test. It was selected low values for Z because the desired phenotypes were the ones with lower scores of disease and less number of days to flowering. The phenotypic selection using both plant height data and Z index had an intensity of 30% (Table 1). Besides being easy to estimate, the use of Z index has the advantage of allowing to perform an analysis of variance, since it is estimated one index per plot (Ramalho *et al.*, 2012). Significant differences ($p \leq 0.05$) between genotypes suggest the existence of the genetic variability between progenies, indicating that it is possible to achieve gain with selection using the index.

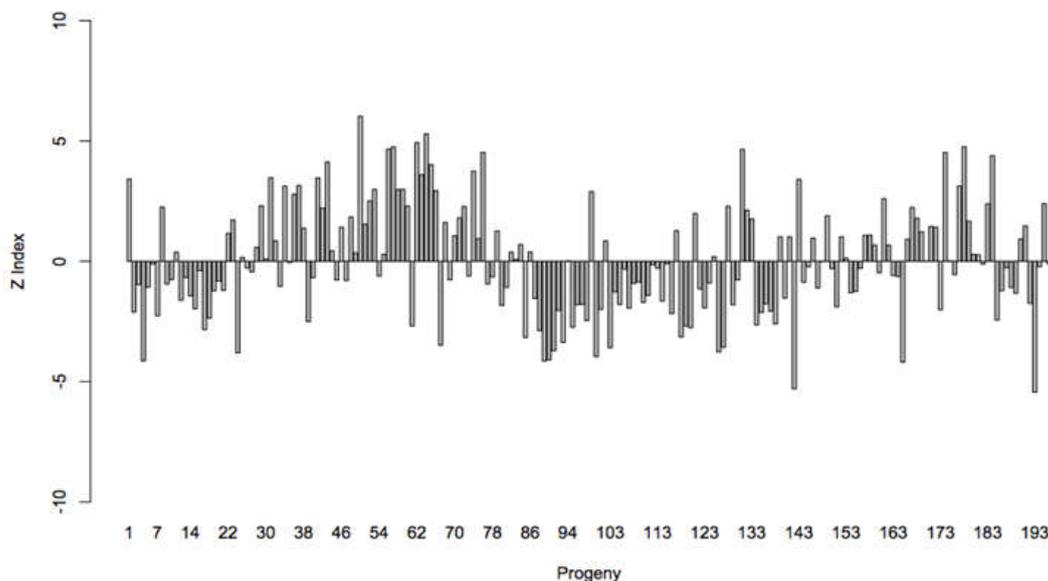


Figure 1. Distribution of the Z values of progenies

Brown spot and leaf scald also commonly occur in Central and South American where temperature and humidity favors fungus development (IRRI, 2015). Leaf scald usually occurs late in the season and is favorable by wet weather, high

The variation of the Z values of progenies can be visualized in Figure 1. The efficiency of the Z index in selecting for multiple characters simultaneously can be checked examining the performance of the progenies selected considering each trait

separately. The performances of the four progenies that showed the best Z index (progenies 24, 89, 90, and 142) and of the four progenies that showed the worse Z index (progenies 11, 44, 49, and 180) are graphically represented in Figures 2 and 3, as proposed by Mendes et al. (2009).

The graphics representing the performance of the progenies in Figure 2 are denominated as “deflated ball”, meaning that the mean of most traits are equal or lower than the population mean.

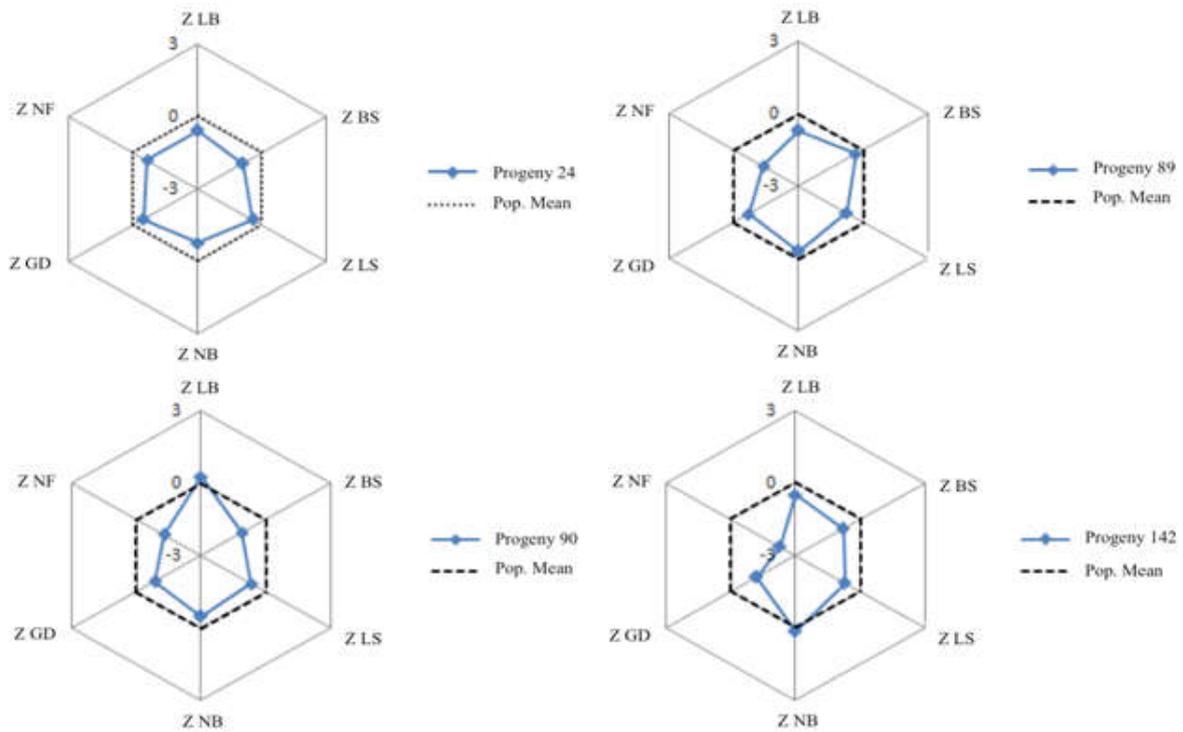


Figure 2. Graphic representation of the estimated Z values for leaf blast resistance (Z LB),brown spot resistance (Z BS), leaf scald resistance (Z LS), neck blast resistance (Z NB), grain discoloration resistance (Z GD), and number of days to flowering (Z NF) of the four progenies (24, 89, 90 and 142) that showed the best Z index

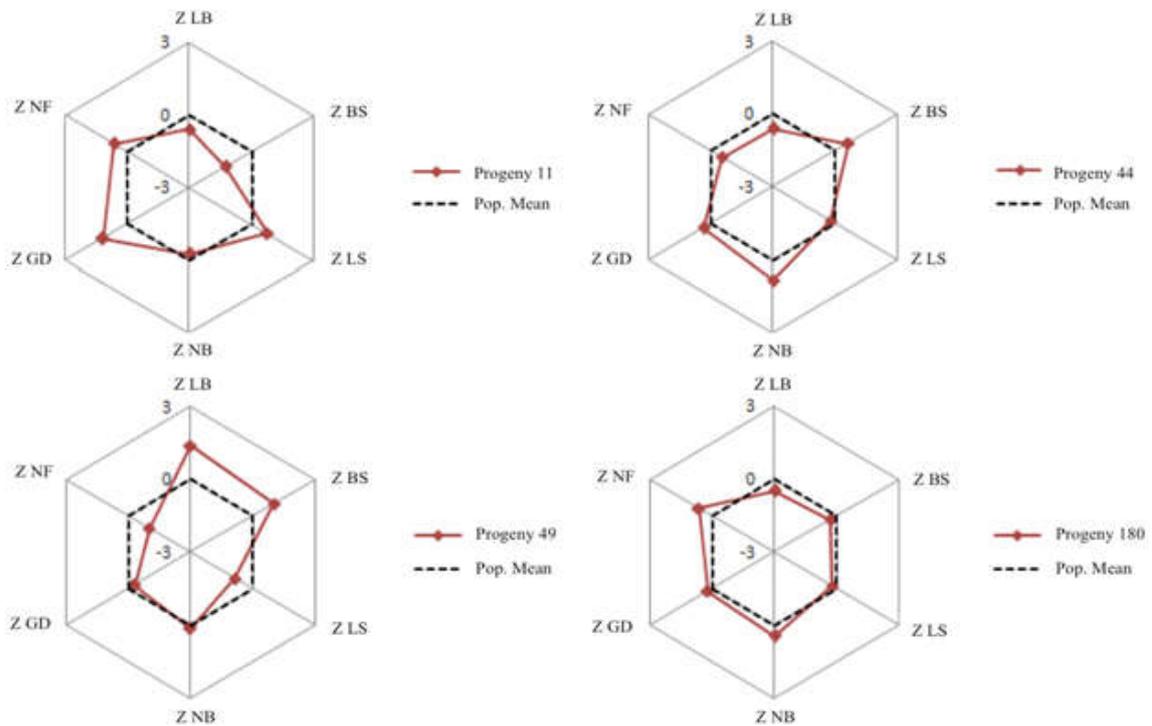


Figure 3. Graphic representation of the estimated Z values for leaf blast resistance (Z LB),brown spot resistance (Z BS),leaf scald resistance (Z LS), neck blast resistance (Z NB), grain discoloration resistance (Z GD), and number of days to flowering (Z NF) of the four progenies (11, 44, 49 and 180) that showed the worse Z index

On the other hand, the graphics representing the performance of the progenies in Figure 3 are denominated “full ball”, meaning that the mean of most traits are higher than the population mean. Since breeders are interested in lower scores of disease and less number of days to flowering, in this case, the progenies that produced deflated ball graphics were preferable. In Figure 2, it was possible to highlight the progenies 24 and 89, which showed low means for all traits compared to the population mean. The precocity of the progeny 142 was also outstanding, indicating that this line should have attention in breeding programs aiming to reduce rice lines cycle. In the graphical representation of the less promising progenies (Figure 3), it was possible to highlight the progeny 49, which was greatly susceptible to leaf blast and brown spot. Therefore, the use of Z index was efficient, since the progenies selected by the index were also superior considering the traits separately. It was also clear how the index made it easier to select for multiple traits, enhancing the efficiency of selection in breeding programs.

Conclusions

The Z index was efficient in selecting progenies for multiple traits simultaneously. The progenies 24 and 89 stood out in all evaluations and must have attention in Brazilian Upland Rice Breeding Programs.

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