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Estimation of Adaptability and Stability of Nellore Sires, based on the Productive Progeny Performance Raised in Brazilian Savanna

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Abstract: The study investigates the performance and adaptability of Nellore sires across different regions, focusing on weight traits at 205 days (W205) and 550 days (W550). Analysis reveals significant variations in progeny weight means among evaluated sires, highlighting the importance of sire selection for herd improvement. Notably, certain sires consistently exhibit superior weight traits across diverse environmental conditions, indicating their potential for widespread applicability. Regression analysis further elucidates the adaptability of sires to specific herds, with some demonstrating adaptability to favorable conditions while others exhibit stability across various regions. Additionally, variance components and coefficients of determination serve as valuable tools for assessing stability and predictability in sire performance. Findings emphasize the critical role of informed sire selection in enhancing herd productivity and resilience. By leveraging these insights, livestock producers can optimize breeding strategies to achieve long-term profitability and sustainability in diverse environmental contexts.

Keywords: Animal Production, Cattle, Genotype Environment

Introduction

The Brazilian savanna stands as the largest expanse of savanna formation in South America, representing a pivotal biome within Brazil (Miranda *et al*., 2009). Encompassing a spectrum of vegetation, from expansive grasslands to dense woodlands, this region poses unique challenges and opportunities for livestock breeding (De Souza *et al*., 2018). The advent of artificial insemination has revolutionized the integration of genetically superior sires across varying environmental gradients. However, studies have underscored the complex interplay between genotype and environment (Ambrosini *et al*., 2016; Macneil *et al*., 2017; Silveira, 2019; Silva Neto *et al*., 2023), complicating the selection of superior sires for optimal performance.

Assessments of genetic parameters and analyses of genotype-environment interaction have been conducted to understand weaning weight variations in livestock production (Souza *et al*., 2003; Sejian *et al*., 2015; Escarcha *et al*., 2018; Souza *et al*., 2022). Studies have identified causes of non-genetic variations and observed station region interactions influencing animal weights within Nelore Mocho herds, particularly in dairy livestock regions. Furthermore, investigations into genotype-environment interaction have been conducted to explore post-weaning weight dynamics of Nellore cattle across different states, such as Maranhão, Mato and Pará. Additionally, research has examined the impact of genotype environment interaction on birth weight, as well as weight at 205 and 550 days of age in Nellore cattle, shedding light on the intricate relationship between genetic makeup and environmental factors in determining cattle weight traits.

Recognizing the importance of identifying adapted and stable sires tailored to diverse ecosystems is pivotal for enhancing productivity and optimizing breeding strategies (Marçal *et al*., 2014). While traditional analysis methods, such as joint variance analysis, offer insights into sire-herd interactions through F-tests, they often lack

granularity regarding sire performance across different herd disparities. Conversely, adaptability and stability studies provide a nuanced understanding by identifying sires capable of consistent performance across varying production levels (Marçal *et al*., 2014, Silveira, 2019; Silva Neto *et al*., 2023).

Defined by Cintra (2007), genotypic adaptability and stability signify the capacity of genetic combinations to exploit environmental stimuli and exhibit predictable behavior in response to environmental cues, respectively. Various methodologies have been proposed to assess these parameters, each differing in estimation techniques and interpretation nuances (Changizi *et al*., 2014; Silveira, 2019).

Against this backdrop, our study aims to estimate the stability and adaptability parameters of Nellore sires, leveraging the genetic diversity inherent in the breeding population. Specifically, we focus on linear regression methodologies to assess weight at 205 days (P205) and 550 days (P550) across diverse production levels. By elucidating the performance patterns of Nellore sires in varied environments, we seek to contribute to the optimization of breeding practices and the enhancement of livestock productivity within the Brazilian Savanna. Research investigating bull performance across various regions of the country has revealed the presence of genotype x environment interaction. Studies conducted by authors like Souza *et al.* (2004); Espasandin *et al.* (2011); Amaral *et al.* (2014); Souza *et al*. (2022), which explored trends, phenotypic and genetic parameters of growth traits in Nellore cattle across different regions of Brazil, have highlighted the notable impact of genotype × environment interaction.

This study's significance lies in its pursuit of optimizing livestock breeding practices, particularly focusing on Nellore sires within the dynamic environmental landscape of the Brazilian Savanna. By identifying sires with high adaptability and stability through advanced linear regression methodologies, the research aims to enhance livestock productivity and resilience. Such insights are crucial for sustainable breeding practices, enabling farmers to select genetically superior sires capable of consistent performance across diverse production levels. Ultimately, this research contributes not only to the improvement of breeding strategies but also to the broader goal of promoting sustainable livestock production in the Brazilian Savanna biome and beyond.

The aim of this study was to assess the stability and adaptability parameters of Nellore sires by analyzing genetic variations within the breeding stock and their progenies' development. This was achieved through the utilization of linear regression methodologies to evaluate weight at 205 days (P205) and 550 days (P550) across various production levels.

Materials and Methods

Information from 2,366 progenies of ten Nelore bulls, born between 1986 and 2012, belonging to the National Archive of Zebu Breeds (ABCZ) was used. The animals were raised on pasture in three production regions (Souza *et al*., 2003). The classification considered the production system, level of technology, quality and productivity of resources and racial type of the bovine herd. The animals were evaluated in the Regions of Alto Taquari-Bolsão (RATB), Campo Grande-Dourados (RCGD) and West of São Paulo-Paraná (RSPR).

The study estimated Expected Progenies Differences (DEPs) for specific traits in each region of selected bulls. Data analysis involved evaluating performance characteristics of weight at 205 days of age P205 and at 550 days of age P550, (Table 1).

Table 1: Mean (kg) and standard deviations of the data of the DEPs of each sire, by region, for weights at P205 and P550 days of age

P205		Region	
Sires	RATB*	RCGD	RSPR
1	4.01±3.78 (89**)	-2.30±1.97 (007)	0.34±03.18 (12)
2	9.71±3.80 (36)	5.64±4.63 (013)	-0.86±03.22 (24)
3	3.84±3.73 (47)	-1.35±4.17 (010)	-2.13±02.84 (08)
4	3.75±2.78 (24)	7.67±3.86 (162)	3.84±03.48 (06)
5	0.69±2.68 (22)	7.98±3.93 (022)	4.46±03.25 (06)
6	3.80±3.05 (36)	4.90±4.56 (147)	1.10±03.64 (12)
7	5.15±3.97 (30)	1.27±4.09 (088)	4.55±04.27 (05)
8	-1.21±2.77 (49)	-1.21±1.81 (019)	2.55±02.80 (17)
9	1.79±2.60 (25)	-3.12±3.85 (062)	0.76±02.95 (38)
10	1.11±3.47 (39)	1.72±3.87 (094)	2.70±03.64 (34)
P550		Region	
Sires	RATB	RCGD	3
1	41.76±10.23 (89)	33.84±05.41 (007)	40.88±09.92 (12)
2	38.69±16.78 (36)	28.05±17.99 (106)	14.34±15.74 (24)
3	39.12±10.65 (47)	24.36±16.36 (010)	32.12±12.83 (08)
4	-0.63±10.64 (24)	20.48±11.98 (162)	8.96±12.37 (06)
5	01.30±06.81 (22)	20.17±08.17 (022)	10.67±10.26 (06)

Table 1: Continue

6	-1.35±06.74 (36)	04.20±11.40 (147)	-5.52±11.90 (12)
7	2.21±12.66 (30)	03.99±09.99 (088)	6.15±11.29 (05)
8	-0.24±09.48 (49)	03.95±05.66 (019)	2.68±08.50 (17)
9	5.15±07.00 (25)	03.66±12.56 (062)	3.83±09.61 (38)
10	11.39±13.15 (39)	03.59±10.50 (094)	2.69±10.24 (33)

** ( ) Observation number, * Region: RATB: Alto Taquari-Bolsão, RCGD: Campo Grande-Dourados, RSPR: Oeste de São Paulo -Paraná

The dataset's traits underwent analysis of variance within each region to determine genetic variability between the mean values of the tested bulls' progenies and to determine the extent of genetic parameters. A joint analysis of variance was conducted to uncover interactions between bulls and regions.

The regression model used in the study functioned as a dataset about different bulls and their performance in various herds. The analysis revealed that the sum of herd indices for each bull equals zero, enabling the calculation of the average performance for each bull. To estimate stability and adaptability, a model was used where a bull's performance depends on the herd index along with additional factors (Marçal *et al*., 2014; Silveira, 2019).

The General Linear Models procedure (GLM) of the program Statistical Analysis System (SAS), the student was used in the analysis of joint variance and in the manipulation of the database. For the analysis of dissimilarity between herds, adaptability and stability, the genes program was used: A computational application in genetics and statistics, Windows version, according to Silveira (2019).

Results and Discussion

Adaptation is described as either genetic (long-term) or non-genetic (short-term) responses to challenges or stressors. Short-term responses, which also have a genetic component, vary among animals in their ability to cope with stressors like high temperatures. Non-genetic adaptations, like changes in food intake and respiratory rate in response to heat, are typically short-term. Various management strategies, such as providing shade and handling food appropriately, are mentioned as short-term responses to acute challenges (Gaughan, 2019; Changizi *et al*., 2014; Silveira, 2019).

The fluctuating challenge of adapting to environmental conditions and the resultant impacts on animal performance, such as milk production and fertility, are noted. However, the section lacks a thorough discussion of the tables provided, including Table 2, which summarizes the analysis of variance for characteristics like weaning weight and yearling weight, considering the sire × region interaction. This interaction indicates variability in sire performance across different regions but doesn't provide insight into progeny performance. Additionally, the absence of comparisons with previous research limits contextualization. Integrating findings more cohesively, emphasizing study-specific outcomes and thoroughly discussing referenced tables would greatly improve the section's clarity and impact.

Table 2: Summary of the analysis of variance for the characteristics, weaning weight (W205) and yearling weight (W550), considering the sire × region interaction

	W205	W550
Source of variation	MS	MS
Sire	5045.17*	47822.21*
Region	1885.37*	5453.33*
Sirex region	1861.59*	10531.66*
Error	2071972.11	10564097.63
CV (%)	12.72	13.86
R2 (%)	34.50	50.63

CV: Coefficient of variation, MS: Means Square, R^2: Coefficient of determination, *: Significance level ($p<0.05$)

This can benefit cattle breeders from the perspective of genetic improvement. Understanding the stability and adaptability of bulls in different regions can help in selecting breeders more suitable to the specific environment of the farm. This can lead to genetic improvement of the herd, resulting in more resilient and productive animals. Resource management, when recognized and allowing observation of how bulls behave in different environmental conditions, enables the farmer to adjust management practices, such as feeding and shelter, to optimize herd performance and minimize the impacts of environmental stress. In this way, strategic planning can be developed. Understanding the interactions between bulls and regions can inform strategic decisions, such as the distribution of the herd in different areas of the farm or the choice of bulls more suitable for business expansion or diversification. Based on the aforementioned, productivity maximization can be achieved. By selecting bulls with greater stability and adaptability, farmers can increase herd efficiency and productivity, resulting in better long-term financial returns. In summary, understanding the stability and adaptability of bulls can help farmers make more informed and effective decisions to improve the health, productivity and profitability of their herds.

In the RATB and RCGD regions for the W205 and the RCGD for the W550, positive performances were obtained for the indices, presenting the best performance averages of the sires' offspring (Table 3).

Table 3: Estimates of the mean of the progenies of the sires and herd index of the region (Ij) for the traits of weaning weight (W205) and yearling weight (W550)

	W205		W550	
Region	Average	(Ij)	Average	(Ij)
RATB	186.60	0.7490	333.24	-3.46
RCGD	187.91	2.0659	343.04	6.34
RSPR	183.03	-2.8149	333.82	-2.88

RATB = Alto Taquari-Bolsão, RCGD = Campo Grande-Dourados, RSPR = West of São Paulo-Paraná

Table 4: Estimates of the parameters of adaptability (β_{oi}, β_{1i}) and stability (α^2_{di}) and coefficient of determination (RCGD) of the ten sires evaluated for the characteristics of performance weight adjusted for the 205 days (W205)

Sire	β_{oi}	β_{1i}	α^2_{di}	RCGD (%)
1	176.45	1.53 ^{ns}	047.03**	35.41
2	180.91	4.41^{++}	024.29*	88.66
3	174.41	2.28 ^{ns}	040.89*	57.83
4	188.46	2.94 ^{ns}	225.50**	32.08
5	197.91	-3.11^{++}	-004.96 ^{ns}	98.01
6	191.53	1.89 ^{ns}	010.36 ^{ns}	71.86
7	203.44	0.62 ^{ns}	039.95*	09.43
8	179.10	-1.50 ^{ns}	002.17 ^{ns}	74.95
9	177.35	-0.48 ^{ns}	-006.25 ^{ns}	70.76
10	188.58	1.42 ^{ns}	006.89 ^{ns}	64.28

ns = non-significant result (p>0.05) according to the t-test used, ++ significant results at 0.1% probability by t-test, ** significant result at the level of 0.1% probability (p<0.001) by the F test

Table 5: Estimates of the parameters of adaptability (β_{oi}, β_{1i}) and stability (α^2di) and coefficient of determination (R2) of the ten sires evaluated for the characteristics of performance weight adjusted at 550 days (W550)

Sires	β_{oi}	β_{1i}	α^2_{di}	R^2 (%)
1	391.08	0.14^{++}	138.34**	00.91
2	358.41	0.52^{++}	1.141.45**	01.41
3	378.51	-0.36^{++}	316.94**	02.47
4	324.35	5.71^{++}	537.32**	78.59
5	330.90	-2.51^{++}	1.340.98**	22.15
6	303.48	2.38^{++}	017.26**	95.21
7	321.37	0.33^{++}	209.42**	03.12
8	315.04	1.79^{++}	54.35**	78.13
9	321.89	2.07^{++}	51.65**	83.36
10	321.98	-0.08^{++}	232.91**	00.15

++ significant results at 0.1% probability by t-test, ** significant result at the level of 0.1% probability (p<0.001) by the F test

The difference in the mean weight of the progenies of the Sires evaluated for the performance traits for P205 varied between 174.41 and 203.44 kg. It was verified in the intercepts (β_{oi}) of W205 in the progenies of different genotypic compositions, that Sires 7, 5, 6, 10 and 4 are parents of progenies with higher W205. Considering the intercepts (β_{oi}) of W205 for the phenotypes of the progenies of the Sires, it appears that sires 1, 3, 4, 6, 7, 8, 9 and 10, based on in the t-test of significance for the angular coefficients (β_{1i}), with the corrected environmental indices for each evaluated environment, they were identified as having general adaptability, that is, they are adapted to different environments. The sire 2 presented the value of ($\beta_{1i} \geq 1$) indicating adaptability to favorable herds. However, sire 5 ($\beta_{1i} \leq 1$) has adaptability to unfavorable herds (Table 4).

The results observed in the RATB and RCGD regions for the W205, as well as in the RCGD region for the W550, demonstrate positive performances in terms of the indices, showcasing the superior performance averages of the sires' offspring. Specifically, when evaluating the mean weight differences among progenies of the assessed sires for the performance traits related to P205, variations between 174.41 and 203.44 kg were identified. Examining the intercepts (β_{0i}) of W205 across progenies of different genotypic compositions, it is evident that sires 7, 5, 6, 10 and 4 are associated with progenies exhibiting higher W205 values. Further analysis of these intercepts (β_{0i}) for W205 across progeny phenotypes reveals that sires 1, 3, 4, 6, 7, 8, 9 and 10 demonstrate general adaptability, as indicated by the significance of the t-test for the angular coefficients (β_{1i}), considering the corrected

environmental indices for each evaluated environment. This suggests their adaptability across different environments. Notably, sire 2 exhibits a β_{1i} value of ($\beta_{1i} \geq 1$), signifying adaptability to favorable herds, whereas Sire 5 displays a β_{1i} value of ($\beta_{1i} \leq 1$), indicating adaptability to unfavorable herds. These findings underscore the nuanced adaptability profiles of different sires, providing valuable insights for cattle breeders in optimizing herd performance across varied environmental conditions. These results are similar to those reported by Silveira (2019).

The values of the components of variance inflicted to the regression deviations (α^2_{di}) and the values of the coefficient of determination (R^2) being used as an auxiliary measure of comparison according to the recommendation of Barros *et al*. (2006), sires 8, 9, 3, 2, 5, 6 and 10 were classified as having high R^2 value (%) above 50%, as high stability, with highly predictable performance in the different regions studied. Genotypes 4, 1 and 7 have low stability (R^2 <50%), that is, they have an unlikely performance.

Souza *et al*. (2004; 2022); Gienapp *et al*. (2008); Thornton *et al*. (2009); Sejian *et al*. (2015); Zhang *et al*. (2017); Escarcha *et al*. (2018); reported the importance of determining the parameters for adaptation to different livestock farming strategies and, therefore, identifying the best animals adapted to each environment. Making adjustments to production, availability of food and water and the responses of animals there is fundamental to the production system as a whole. Therefore, selecting animals that present minimal stress and that carry genes that maximize productivity and performance is what is desired.

The classification of sires based on the values of the components of variance inflicted to the regression deviations (α^2di) and the coefficient of determination (R^2) provides valuable insights into their stability and predictability across different regions. Sires 8, 9, 3, 2, 5, 6 and 10, characterized by high R^2 values above 50%, are deemed to possess high stability, indicating highly predictable performance across the studied regions. Conversely, genotypes 4, 1 and 7 exhibit low stability (R^2 <50%), suggesting less predictable performance. These findings align with previous research by Souza *et al*. (2003; 2022); Sejian *et al*. (2015); Gienapp *et al*. (2008); Thornton *et al*. (2009); Zhang *et al*. (2017); Escarcha *et al*. (2018), which emphasize the significance of determining adaptation parameters for livestock farming strategies. By identifying animals best suited to specific environments, adjustments to production, food and water availability and animal responses can be optimized, thereby enhancing the overall production system. The selection of animals exhibiting minimal stress and carrying genes conducive to maximizing productivity and performance emerges as a fundamental goal, underscoring the importance of strategic breeding decisions in livestock management.

The progenies of the sires evaluated for the W550 showed differences in the weight mean in the regions between 378.51 and 303.48 kg with a variation of 19.82%. Sires 1, 3, 2, 5 and 4 stood out with the highest W550 values of their progenies (Table 5). The intercepts (β_{oi}) represent the mean P550 values of the progenies of the studied sites. Based on the t-test of significance for the slope coefficients (β_{1i}), with the corrected environmental indexes for each evaluated environment, sires 4, 6, 8 and 9 were identified with the values ($\beta_{1i} \geq 1$) indicating adaptability to favorable herds. The values of the components of variance inflicted on the regression deviations (α^2_{di}) and the values of the coefficient of determination (R^2) are used as an auxiliary measure for comparison according to the recommendation (Barros *et al*., 2006; Marçal *et al*., 2014; Silveira, 2019; Silva Neto *et al*., 2023). Sires 8, 9, 4 and 6 were classified as having high R^2 value (%) above 50%, as having high stability and predictable performance in the different regions studied.

The evaluation of progenies from different sires for the trait W550 revealed significant variations in weight mean across regions, ranging from 303.48-378.51 kg, indicating a substantial 19.82% difference. Among the sires, sires 1, 3, 2, 5 and 4 exhibited the highest mean W550 values for their progenies, demonstrating their potential for producing offspring with greater weight. The intercepts (β_{oi}) serve as representations of the mean P550 values of the progenies from the studied sires, offering insights into their overall performance. Through the t-test of significance for the slope coefficients (β_{1i}), adjusted for environmental factors in each region, Sires 4, 6, 8 and 9 were identified as having adaptability to favorable herds, as evidenced by values of ($\beta_{1i} \geq 1$). Additionally, the components of variance inflicted on the regression deviations (α^2di) and the coefficient of determination (R^2) were employed as supplementary measures for comparison, following the recommendation of Barros *et al*. (2006). Sires 8, 9, 4 and 6 were classified as possessing high R^2 values (>50%), indicative of high stability and predictable performance across diverse regions, thereby underlining their potential for consistent performance and suitability for various breeding programs (Souza *et al*. 2004; Macneil *et al*., 2017; Silva Neto *et al*., 2023).

Escarcha *et al*. (2018) reported a series of factors that can directly affect adaptation strategies. These include the lack of information on the various production systems; adequate investigation into where the genotype will be placed; infrastructure and market organization.

The study delves into the stability and adaptability parameters of Nellore sires across different regions, employing advanced linear regression methodologies to evaluate weight traits at 205 days (P205) and 550 days (P550) across diverse production levels. Findings underscore the nuanced adaptability profiles of various sires, offering valuable insights for cattle breeders in optimizing herd performance across varied environmental conditions. Notably, sires exhibiting high stability and

predictable performance across diverse regions are identified, providing a basis for informed breeding decisions aimed at enhancing herd productivity and resilience. The classification of sires based on stability parameters aligns with previous research emphasizing the significance of determining adaptation parameters for livestock farming strategies. Additionally, significant variations in progeny weight mean across regions highlight the need for tailored breeding programs to maximize offspring performance. By integrating findings and addressing cited factors affecting adaptation strategies, this study contributes to a more comprehensive understanding of genotype-environment interactions and informs strategic breeding decisions for sustainable livestock production (Souza *et al*. 2003; 2004; 2022; Sejian *et al*., 2015; Escarcha *et al*., 2018).

Conclusion

Through extensive analysis, it's clear that sire selection profoundly influences progeny performance and adaptability in varied environments. Sires with higher weights and favorable adaptability indicators significantly enhance herd improvement efforts. Stability, gauged by high R^2 values, ensures consistent performance across regions. These insights emphasize the critical need for informed sire selection, considering both performance and adaptability metrics. Utilizing such knowledge enables livestock producers to refine breeding programs, elevating productivity, resilience and ultimately, profitability.

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Author’s Contributions

úlio César De Souza: Conceptualized the project and provided advisory support. Conducted software development and formal analysis.

Fábio Rafael Leão Fialho: Developed the fundamental idea. Analyzed and interpreted the data. Reviewed and edited the written content.

Carolina Fregonesi De Souza: Reviewed and edited the written content.

Carlos Henrique Cavallari Machado and Mariana Pereira Alencar: Curated the data.

Paulo Bahiense Ferraz Filho and André Luiz Julien Ferraz: Analyzed the data. Made adjustments to the methodology.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and that no ethical issues are involved.

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