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BUSINESS INTELLIGENCE TOOLS APPLIED IN THE ASSESSMENT OF THE GENOTYPE X ENVIRONMENT INTERACTION IN ELEPHANT GRASS

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ABSTRACT

Objective: This study aimed to present a tool for evaluating the genotype x environment interaction using dashboards developed with Business Intelligence (BI) techniques in multiple elephant grass experiments for bioenergy production.

Theoretical Framework: Elephant grass, among the crops dedicated to the production of biomass energy, is considered a prominent alternative. It is widely known to breeders that, when evaluating genotypes in various environments, consistent behavior is not observed. This differentiated response of genotypes to environmental variation is called genotype x environment interaction. As the main purpose of a breeding program is to select genotypes of consistent and high productivity, in the most diverse environments, the interaction of these factors can represent a problem for breeders, as it reduces the precision in the selection from one environment to another.

Method: The tool selected for the development and manipulation of dashboards, provided by Google, is called Looker Studio, which allows the unification of several databases in a single environment. This integration facilitates the manipulation, creation and development of interactive management reports, promoting a dynamic and personalized visualization of information, an essential feature for analyzing and interpreting data in complex scenarios such as genotype x environment interaction.

Results and Discussion: BI tools prove to be a promising strategy for interpreting the genotype x environment interaction in multiple elephant grass experiments for bioenergy production. These tools allow researchers to quickly and dynamically visualize this phenomenon, providing ease of interpretation of large data sets.

Research Implications: The theoretical and practical implications of this research are valuable for evaluating the genotype x environment interaction in elephant grass, as they allow collecting, storing, processing and visualizing large amounts of data efficiently, allowing users to identify patterns and trends in the data that assist in making more assertive decisions.

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Originality/Value: This study contributes to the evaluation of elephant grass genotypes for biomass energy production.

Keywords: Elephant Grass, Genotype x Environment Interaction, Bioenergy, Decision Making.

FERRAMENTAS DE BUSINESS INTELLIGENCE APLICADA NA AVALIAÇÃO DA INTERAÇÃO GENÓTIPO X AMBIENTE EM CAPIM ELEFANTE

RESUMO

Objetivo: O presente estudo objetivou apresentar uma ferramenta para avaliação da interação genótipo x ambiente usando dashboards desenvolvidos com técnicas de Business Intelligence (BI) em múltiplos experimentos de capim-elefante voltados para a produção de bioenergia.

Referencial Teórico: O capim-elefante, entre os cultivos dedicados à produção de energia da biomassa, é considerado uma alternativa de destaque. É de amplo conhecimento dos melhoristas que, ao se avaliar genótipos em vários ambientes, não se nota um comportamento consistente dos mesmos. Esta resposta diferenciada dos genótipos à variação do ambiente é denominada interação genótipo x ambiente. Como a principal finalidade de um programa de melhoramento é selecionar genótipos de consistente e elevada produtividade, nos mais diversos ambientes, a interação desses fatores pode representar um problema para os melhoristas, por reduzir a precisão na seleção de um ambiente para outro.

Método: A ferramenta selecionada para o desenvolvimento e manipulação dos dashboards, provida pelo Google, é chamada de Looker Studio, a qual possibilita a unificação de diversas bases de dados em um único ambiente. Essa integração facilita a manipulação, criação e desenvolvimento de relatórios gerenciais interativos, promovendo uma visualização dinâmica e personalizada das informações, característica essencial para a análise e interpretação de dados em cenários complexos como o da interação genótipo x ambiente.

Resultados e Discussão: As ferramentas de BI mostram-se uma estratégia promissora para a interpretação da interação de genótipo x ambiente em múltiplos experimentos de capim-elefante para a produção de bioenergia. Estas ferramentas possibilitam ao pesquisador uma visualização rápida e dinâmica deste fenômeno proporcionando facilidades de interpretação de grandes conjuntos de dados.

Implicações da Pesquisa: As implicações teóricas e práticas desta pesquisa são valiosas para a avaliação da interação genótipo x ambiente em capim-elefante, pois permitem coletar, armazenar, processar e visualizar grandes quantidades de dados de maneira eficiente, permitindo que os usuários identifiquem padrões e tendências nos dados voltadas para tomadas de decisões mais assertivas.

Originalidade/Valor: Este estudo contribui para a avaliação de genótipos de capim elefante para produção de energia de biomassa.

Palavras-chave: Capim-Elefante, Interação Genótipo x Ambiente, Bioenergia, Tomada de Decisão.

HERRAMIENTAS DE INTELIGENCIA DE NEGOCIOS APLICADAS EN LA EVALUACIÓN DE LA INTERACCIÓN GENOTIPO X AMBIENTE EN PASTO ELEFANTE

RESUMEN

Objetivo: El presente estudio tuvo como objetivo presentar una herramienta para evaluar la interacción genotipo x ambiente a través de paneles desarrollados mediante técnicas de Inteligencia Empresarial (BI) en múltiples experimentos de pasto elefante dedicados a la producción de bioenergía.

Marco Teórico: El pasto elefante, entre los cultivos dedicados a la producción de energía de biomasa, se considera una alternativa destacada. Los criadores saben ampliamente que, al evaluar genotipos en diversos entornos, no se observa un comportamiento consistente. Esta respuesta diferenciada de los genotipos a la variación ambiental se llama interacción genotipo x ambiente. Como el objetivo principal de un programa de mejoramiento es seleccionar genotipos de alta y consistente productividad, en los más diversos ambientes, la interacción de estos factores puede representar un problema para los mejoradores, ya que reduce la precisión en la selección de un ambiente a otro.

Método: La herramienta seleccionada para el desarrollo y manipulación de cuadros de mando, proporcionada por Google, se denomina Looker Studio, que permite unificar varias bases de datos en un único entorno. Esta integración facilita la manipulación, creación y desarrollo de informes de gestión interactivos, promoviendo una visualización dinámica y personalizada de la información, característica esencial para el análisis e interpretación de datos en escenarios complejos como la interacción genotipo x ambiente.

Resultados y Discusión: Las herramientas de BI demuestran ser una estrategia prometedora para interpretar la interacción genotipo x ambiente en múltiples experimentos con pasto elefante para la producción de bioenergía. Estas herramientas permiten a los investigadores visualizar este fenómeno de forma rápida y dinámica, facilitando la interpretación de grandes conjuntos de datos.

Implicaciones de la Investigación: Las implicaciones teóricas y prácticas de esta investigación son valiosas para evaluar la interacción genotipo x ambiente en pasto elefante, ya que permiten recolectar, almacenar, procesar y visualizar grandes cantidades de datos de manera eficiente, permitiendo a los usuarios identificar patrones y tendencias en los datos dirigidos a tomar decisiones más asertivas.

Originalidad/Valor: Este estudio contribuye a la evaluación de genotipos de pasto elefante para la producción de energía de biomasa.

Palabras clave: Pasto Elefante, Interacción Genotipo x Ambiente, Bioenergía, Toma de Decisiones.

1 INTRODUCTION

Elephant grass [*Cenchrus purpureus* (Schumach) Morrone syn . *Pennisetum purple* Schumach] is a grass widely used in all tropical and subtropical regions of the world. It was described in 1827 and underwent several changes in its classification, belonging to the Poaceae family, subfamily Panicoideae and tribe Paniceae , which is represented by the most important genera of tropical forages (Pereira *et al* ., 2001).

Its center of origin and genetic variability is a large area of tropical Africa, with the main areas of biodiversity being the territories of Guinea, Mozambique, Angola, Zimbabwe and southern Kenya (Pereira *et al* ., 2010). In Brazil, it is considered that its introduction occurred in two moments, the first in Rio Grande do Sul in 1920 and the second in São Paulo in 1921 with cuttings coming from the United States and Cuba, respectively. Over time, its cultivation was disseminated throughout the country due to its broad adaptation to the environment in addition to high production potential and forage quality (Pereira *et al* ., 2010).

Brazil is a country with vast potential for the production of raw materials for energy purposes, due to its favorable edaphoclimatic conditions (climate and soil). Elephant grass is traditionally used for animal feed, however, it has attracted considerable attention for use as a raw material for bioenergy production, especially due to its photosynthetic efficiency (carbon fixation mechanism), high biomass production, longevity, accelerated growth, easy adaptation, in addition to its chemical properties and ability to fix nitrogen (Ferreira *et al* ., 2021).

If properly managed, elephant grass can continue to produce biomass for several years due to its ability to regrow and persistence. In addition, it has an advantage in terms of the recommended cutting age for use for energy purposes. Elephant grass can be cut more frequently when compared to sugarcane and eucalyptus, other species that also serve as a source of biomass for bioenergy production (EMBRAPA, 2015).

With the growth of Industry 4.0, the amount of data generated by electronic devices tends to increase due to the fact that they are increasingly integrated into the global network. When processed, this data is capable of generating information that was unknown to people until years ago, information that can leverage several non-existent segments or significantly improve others. Based on this universe of data in rural areas, there is a need to generate information so that producers can have greater capacity in their production. Just as data that travels through the network can undergo changes, in living beings this data originating from genotypes, together with their interactions with the environment, transforms beings, molding and adapting them so that they can be better cultivated.

Knowing how to identify and qualify which cultivar or genotype best relates to the region provides investment security for the producer. However, to obtain this analysis, a large database must be interpreted so that, in the end, the relationships show the best grass for the environment. The genotype x environment interaction can be understood as the differentiated response of genotypes to environmental variation. Since the main purpose of a breeding program is to select genotypes with consistent and high productivity, in the most diverse environments, the interaction of these factors can represent a problem for breeders , as it reduces the accuracy in selecting from one environment to another (Ferreira *et al* ., 2021), in addition to working with a database that is difficult to manipulate and visualize.

Therefore, interaction is a complicating factor when recommending superior cultivars, requiring the adoption of measures to control or minimize their effects (Cruz *et al.* , 2004). In this context, the study of genotype x environment interaction requires knowledge of the environmental factors that determine the differentiated behavior of genotypes in different environments and/or harvests. Therefore, the development of a *Business Intelligence* (BI) tool (Cruz *et al* ., 2014), or Business Intelligence, is a set of processes, technologies and tools that transform raw data into relevant information, helping companies make more strategic and effective decisions (Batista, 2012). This becomes very useful for breeding programs, because when genotypic and environmental information is accessible, it is possible to evaluate their effects and propose alternatives for their exploitation for the benefit of the farmer (GAUCH *et al* ., 2008). It is with this proposal that the present work presents a visual analysis of the data through *dashboards* developed via BI techniques with the purpose of facilitating the interpretation of the genotype x environment interaction in multiple elephant grass experiments dedicated to bioenergy production.

2 MATERIALS AND METHODS

A systematic literature review was conducted in the main databases with the purpose of identifying the main scientific articles that address BI tools and methodologies applied to the analysis of Genotype x Environment interactions. Based on this analysis, the main BI tools were evaluated regarding their suitability to the study requirements, resulting in the selection of the *Google Looker Studio tool* as the most suitable platform for the development and visualization of interactive *dashboards* .

The tool for developing and manipulating data is provided by Google, and its use involves unifying several databases into a single point for the manipulation, creation and development of management reports (*dashboards*). Google's tools were chosen because of their integration, easy sharing within teams and easy distribution across different types of media, and because they can share the dashboards created via HTML code. In order to manage the data in table format, the *Google Sheets application was chosen* . This software is analogous to *Microsoft Excel and can create tables in a structured manner. Google Looker Studio* was used to create the *dashboards* . This tool is capable of linking the databases and thus creating the necessary *dashboards* .

The data were obtained from Embrapa Dairy Cattle and extracted for analysis, with the purpose of identifying the most relevant relationships. The main information included precipitation, climate, dry matter production, location, average of genotypes and cuts. From this database, the data were crossed to generate *dashboards* and select the best types to be used. The most important crosses involved dry matter production with precipitation, dry matter production with air temperature, and the average of genotypes in different locations and cuts.

2.1 BASE AND FIELD EXPERIMENTAL DATA COLLECTION

Experimental data were obtained from multiple environmental trials of elephant grass clones cultivated for bioenergy production purposes. Data collection was carried out between

2015 and 2018 in different environments, distributed in six municipalities: Nossa Senhora das Dores-SE , Marechal Deodoro (AL), Sinop (MT), Planaltina (DF), Coronel Pacheco (MG) and Bagé (RS). The characteristic evaluated was the production of total dry matter (Mg ha $^{-1}$ year $^{-1}$), and the trials were composed of up to 21 clones planted in rectangular plots in each experiment (1.2 × 4.0 m), consisting of three rows planted side by side in a randomized block design with three replications.

The cultivars BRS Canará and BRS Capiaçu are commercial clones that served as controls. The clones were planted in 0.20 m deep furrows and fertilization was applied at planting according to soil analysis. Maintenance fertilizer was applied at a rate of 300 kg ha $^{-1}$ year $^{-1}$ of NP $_2$O$_5$-K$_2$O (granular fertilizer mixed 20:05:20) in all environments after each evaluation cut.

Four harvests were performed in experiments 1, 5, and 6, and two harvests were performed in experiments 2, 3, and 4 to obtain the total dry biomass (Mg ha $^{-1}$ year $^{-1}$). Harvests were performed at a cutting height of 0.10 m above ground level. The weight of fresh biomass per plot (kg plot $^{-1}$) was obtained by harvesting a 3 m section in the middle of the rows using a gasoline-powered trimmer. Samples were harvested manually and weighed. A random sample of three complete plants from each plot was selected and weighed to obtain the fresh biomass weight (g). These samples were oven-dried at 56 °C until constant weight, and then the dry matter concentration (%) was calculated.

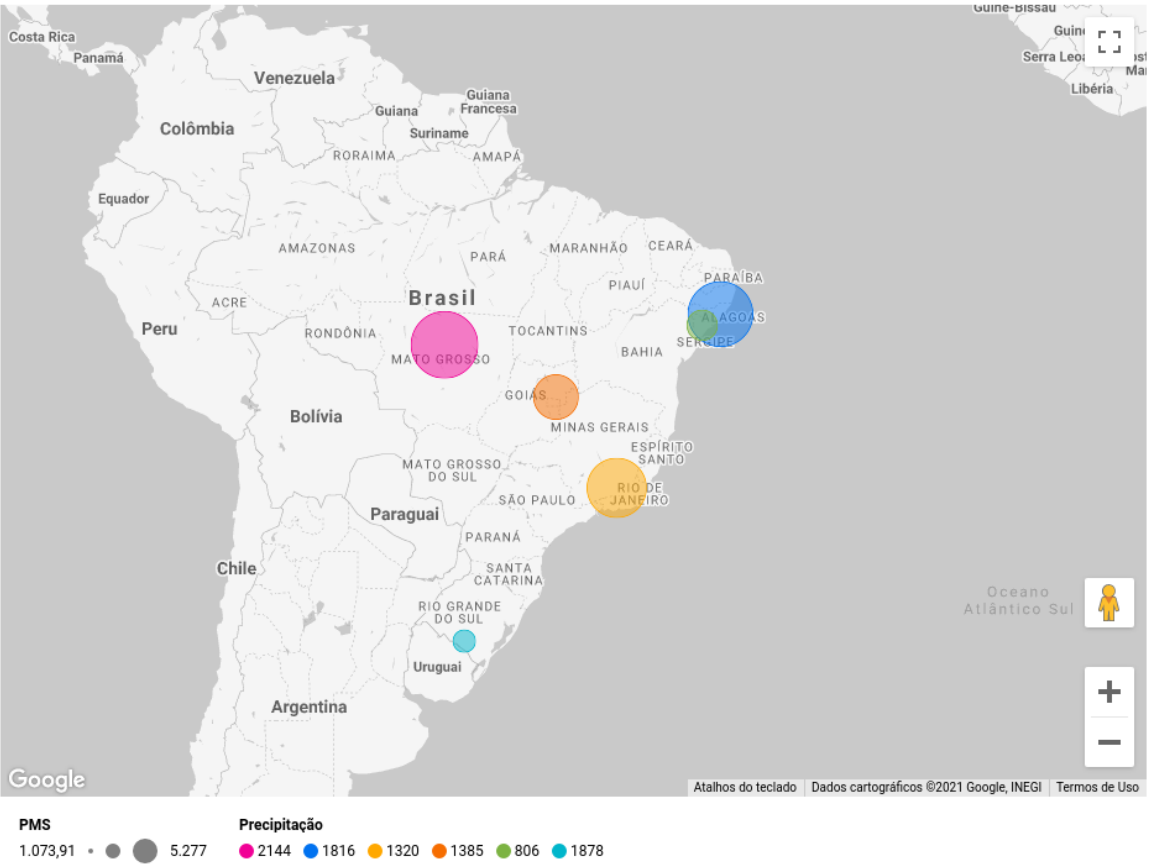
3 RESULTS AND DISCUSSIONS

BI tools have shown to be a promising strategy for interpreting genotype x environment interactions in multiple elephant grass experiments for bioenergy production. These tools allow researchers to quickly and dynamically visualize this phenomenon, facilitating the interpretation of large data sets (Figures 1, 2, 3 and 4).

By assembling the *dashboards* in *Google Looker Studio* , considering the meteorological and biomass production data, it was found that precipitation directly affects the average of the genotypes in the different regions, indicating that, in places where precipitation is high, there is a tendency for the genotypes to show superior performance. Adding to this analysis, we can see that the average air temperature also acts as an influencing factor for the performance of the genotypes. When analyzing this information, it can be highlighted that, in regions where the temperature is on the threshold of 25ºC, the average productivity of the genotypes was high. However, precipitation and temperature should be analyzed together (Figures 1 and 2). This information is in line with what was reported by Pereira *et al* . (2010), who prepared an in-depth review of the elephant grass species and reported that air temperature and precipitation are the main influencing factors in the production and productivity of elephant grass in the different regions where the species is planted.

Figure 1

Relationship of total dry matter production based on precipitation.

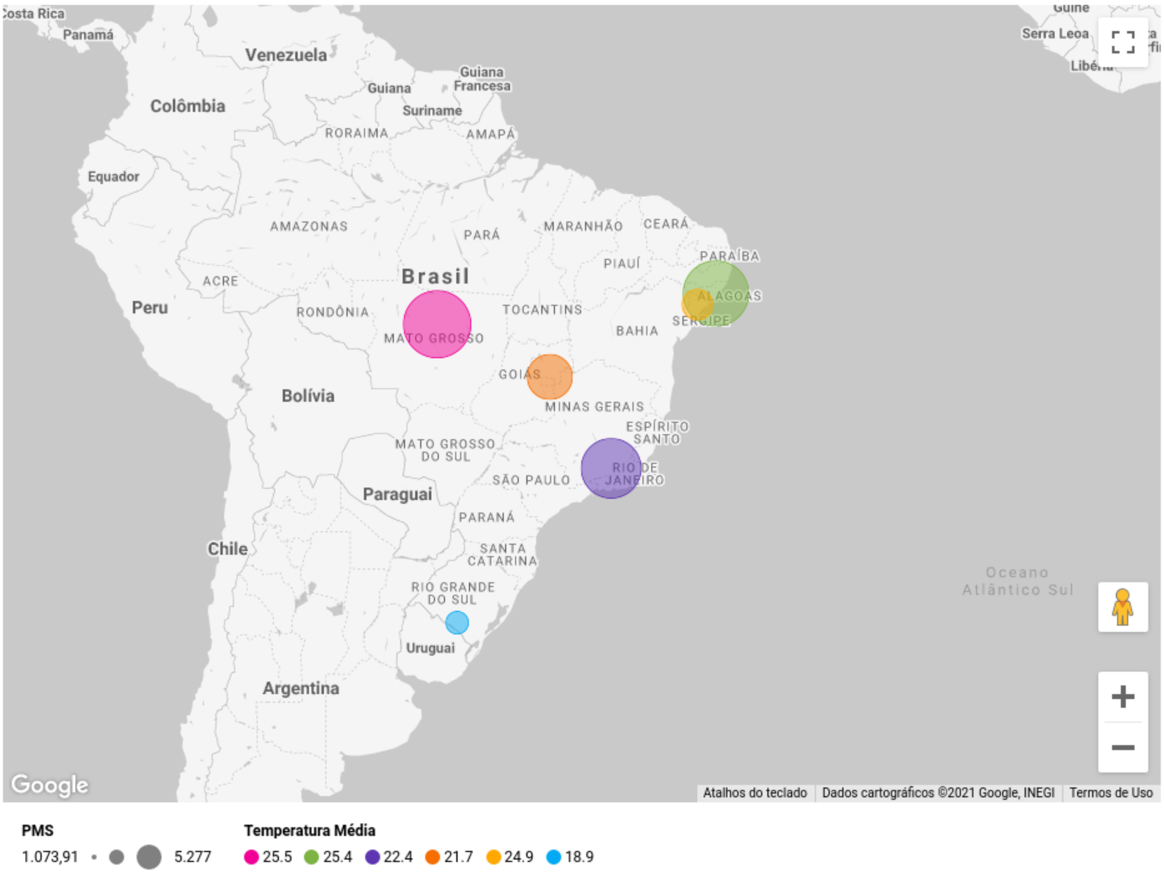


Source: The authors.

Generally, a genotype is stable when its mean is consistently high regardless of the different regions studied. In this scenario, the standout genotypes are BAGCE64-KingGrass and BAGCE22-Taiwan A-144 (Figures 3 and 4), which could be recommended to farmers as broadly adapted genotypes that minimize genotype x environment interaction. These interpretations, supported by BI tools, are consistent with traditional analyses of interpretation of multiple elephant grass experiments (Ferreira *et al* ., 2021) with the advantage of being easy to interpret and dynamic in their construction.

Figure 2

Relationship of total dry matter production based on average air temperature.

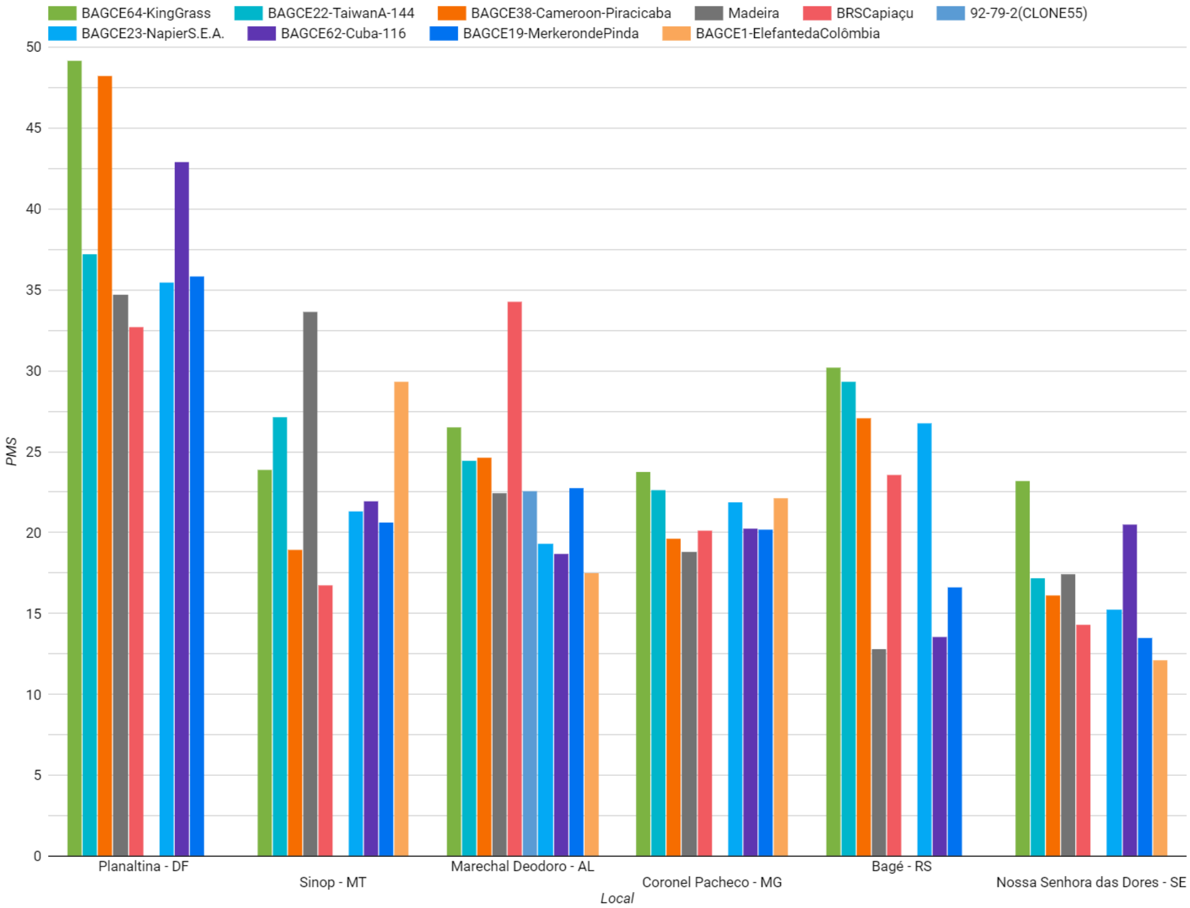


Source: The authors.

It can also be observed that the BRS Capiaçu genotype was specifically adapted to Marechal Deodoro with an average productivity at this location of 34.3 Mg ha $^{-1}$ year $^{-1}$. In addition, it can be seen that the CLONE55 genotype was the most productive in cut 1 while the BAGCE64-KingGrass genotype was the most stable considering the four cuts and could be recommended for farmers who intend to cultivate a stable genotype throughout their harvests. It can also be seen that, in general, the first two cuts are the ones with the highest average productivity and the genotypes decrease in productivity over the cuts.

Figure 3

Average productivity of genotypes from different locations.



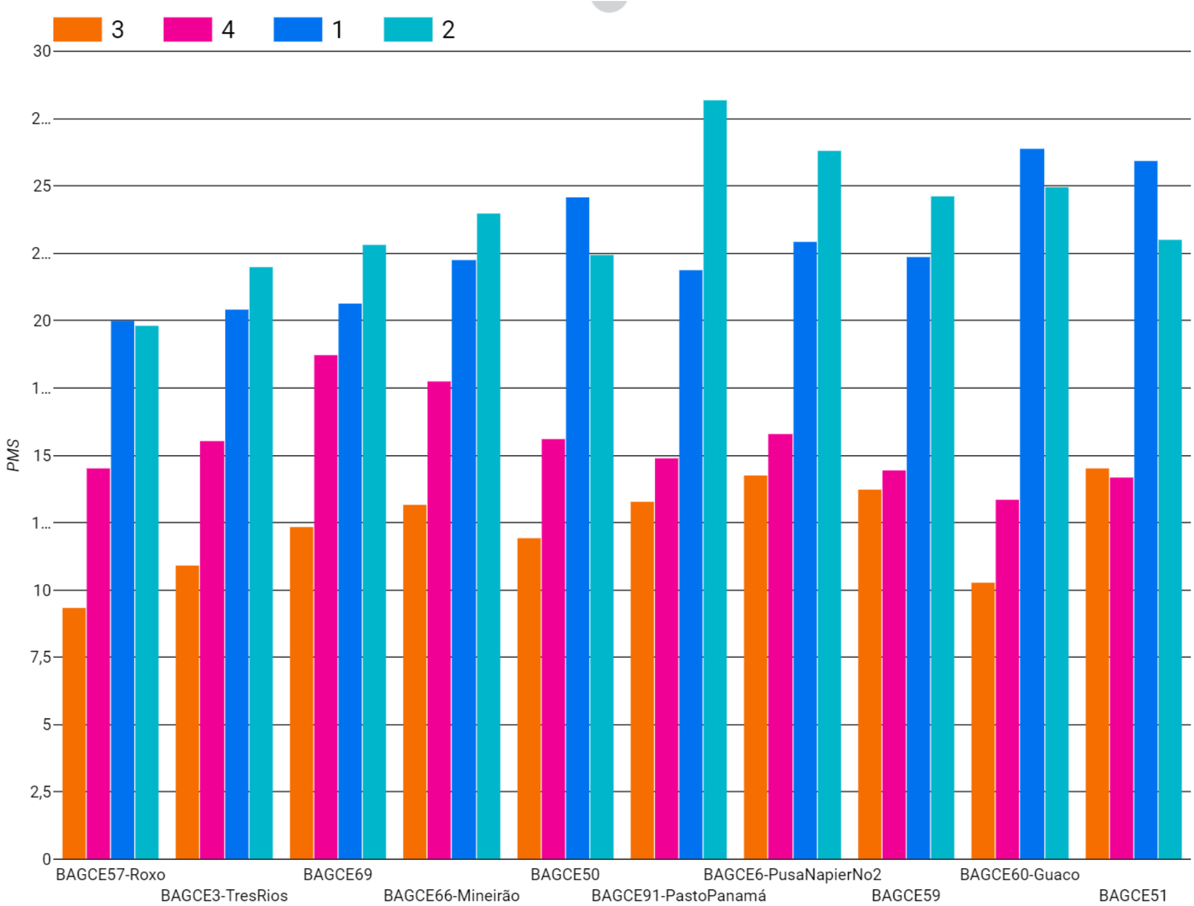
Source: The authors.

In general, BI tools are important for data analysis and decision-making in various sectors, including the assessment of genotype-environment interactions in elephant grass. These tools can be applied to the collection, storage, processing, and visualization of large volumes of data, allowing users to make appropriate decisions within the context in which they conduct research.

The evaluation of genotype x environment interaction in elephant grass is an important research topic in forage production, since elephant grass genotypes can vary in their agronomic and nutritional characteristics, depending on the environment in which they are grown.

Figure 4

Average productivity of genotypes of different cuts.



Source: The authors.

BI tools can be useful in managing information about the characteristics of elephant grass genotypes, as well as in evaluating the environments in which they are grown, allowing researchers to understand how elephant grass genotypes behave under different conditions. In addition, these tools can also be used to detect patterns and trends that may not be evident to the naked eye. This can help researchers identify elephant grass genotypes that are more adaptable to different soil and climate conditions and thus increase the efficiency of forage or energy biomass production.

4 CONCLUSION

BI tools have shown promise in assessing genotype x environment interactions in elephant grass by enabling the efficient collection, storage, processing and visualization of large amounts of data. These capabilities allow users to identify patterns and trends in the data, enabling more assertive decision-making in selecting the best genotypes.

As future work, we suggest developing a BI tool using *Python* and *Flask* to separate itself from existing paid solutions, such as *Google Looker Studio* . This approach would allow the creation of customized *dashboards* and an intuitive web interface for data visualization and analysis. The use of *Python* and *Flask* would allow the creation of a highly customizable and flexible BI solution, adapting to the specific needs of evaluating genotype x environment interactions in elephant grass through the generated graphics and intelligence.

Developing a BI tool with *Python* and *Flask* would enable integration with other technologies, such as databases and information management systems, significantly expanding the capacity for analysis and decision-making. In addition, creating an in-house BI solution would help reduce costs, making it a more accessible, inclusive and sustainable alternative for a diverse audience, without compromising the ability to customize and the efficiency of analyses.

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