RE-EXAMINATION AND META-ANALYSIS OF PREVIOUS RESEARCH AS A TOOL TO EVALUATE THE SUITABILITY OF ROOTSTOCKS IN ADAPTATION TO GLOBAL CHANGE. A STUDY CASE FROM SPANISH VITICULTURE

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Introduction

Meta-analysis (MA) is a method that allows statistical synthesis of the results of several similar individual studies (Figure 1). This term was introduced by Glass in 1976 as a useful tool for the scientific community to pool and summarise the enormous amount of information collected in the literature (Glass, 1976). However, the MA is not only used to quantify the results obtained from different trials, but also allows to Identify characteristics of the different trials where the variability of the results lies, Identify possible areas for future research focus and, present new hypotheses in response to conflicting results

Agronomy, like any other science, has the same need to compile the enormous amount of data and information collected in research work. For this reason, the MA is a methodology of great interest for this science, and researchers are making increasing use of it. If we analyse the use of this tool by consulting the Scopus database on the number of articles in the field of agronomy that use this word ("meta-analysis") in their title or abstract, we can see how, over the years, there has been an exponential increase in their use, nearly no records in the 1990s, around 50 articles per year in the early 2000s, raising up to 250 articles per year in the early 2010s, and currently reaching 750 articles per year. In the case of viticulture, there are already some relevant meta-analysis have also been performed (Payen et al., 2021; Santesteban et al., 2019; Winter et al., 2018), and their informativeness is undeniable.

In a context where viticulture is facing emerging challenges, not only due to the effect of climate change on grape yield and composition, but also due to the social demand for environmental-friendly agricultural management, rootstocks have been already identified as key players to face these challenges (Marín et al., 2020). Therefore, there is a need to re-examine previous works to anticipate which can be the behaviour expected for each rootstock in this changing environment, particularly considering that rootstock performance can only be evaluated after time and space consuming experiments, and that any decision made when establishing a vineyard will condition grape and wine characteristics throughout its entire lifetime. The statistical analysis of the results of previous scientific studies (i.e., a meta-analysis) can be a complementary tool to new field experiments to evaluate rootstock suitability to new conditions.

Research Objectives

The objective of this work is to evaluate the potential interest of the re-examination and meta-analysis of the previous research conducted in Spain on the implication of rootstocks on vine agronomic performance. The originality of the approach is that, unlike most meta-analysis, we constructed a complete database that included both research published in peer-reviewed international journals and technical national journals.

Material and methods

Document search and creation of a database

Document searches were carried out by several methods, including multiple search strategies for the characteristics of the information sought. The databases consulted were Scopus, Google Scholar, Dialnet and Sirius. The search was carried out in English and Spanish, using combinations for the following keywords: “rootstock”, “grapevine”, “vine”, “portainjerto”, “patrón”, “vid” and “vinifera”. No limit was imposed on the date of the study. Additionally, the tables of contents of the most relevant transfer technical journals in Spain (Enoviticultura, Viticultura y Enología Profesional, and Vida Rural).

Once all documents were available, the information provided by each was transferred to an Excel spreadsheet. On the one hand, the metadata of the trial (e.g. region, rootstocks and varieties used, climatic data, soil characteristics, etc) were compiled. On the other hand, the results presented were converted into standardised tabular form. When the data in the original articles were not presented as tables, WebPlotDigitizer, a web-based tool to extract data from plots and images, was used (Rohatgi, 2022)

Statistical Analysis

Response ratios (RR) and 95% confidence intervals were calculated to analyze rootstock effects and significance levels. Data were processed as described by Hedges et al. (1999). Briefly, the RR value for each response value was calculated to quantify the effect of each rootstock compared to the average response on each study according to Eq. 1:

$$RR = \ln ln\, X_r - \ln ln\, X_{ta} \quad \text{(Eq 1)}$$

where X_r is the mean of value for each rootstock and X_{ta} is the mean of the response variable on the study. Among publications used for analysis, few reported the standard error for all the parameters included in this study. Given this, the variable errors within each experiment were not accounted. A weight factor ω was estimated instead for each study using the root of the number of years evaluated in the study. The mean effect of the rootstock of each given variable was calculated using Eq 2

$$RR_p = \frac{\sum_{i=1}^{j} \omega_i \times RR_i}{\sum_{i=1}^{j} \omega_i} \quad \text{(Eq2)}$$

where *i* represents the *i^th^* study and *j* is the total number of studies for a given variable. The percent change (C%) of the investigated variables induced by the rootstock were calculated with Eq 3:

$$C\% = \left(e^{RR} - 1\right) \times 100 \quad \text{(Eq 3)}$$

The effect of the rootstocks was unitless, and the mean rootstock effect and bias correction (95% percent interval) was calculated using R v4.2.1 statistic package (R Core Team, 2015) with RStudio. Numerical data were plotted using RStudio using the package *forestplotter* 0.1.9 (Dayimu, 2022). Principal component analysis (PCA) displaying the relationship between the percent change of the investigated variables in response to the rootstock were plotted using *FactoMineR* (Lê et al., 2008)

Results

Database creation and data compiled for meta-analysis

The search process allowed the complication of a diversity of documents that, after a first independent analysis by two reviewers, were deemed appropriate for inclusion in the database and for further analysis. Altogether, 20 technical documents that included rootstock experimentation conducted at 59 different sites were incorporated to a database. In these documents, experiments with 36 different varieties and a total of 47 rootstocks. Considering each rootstock-variety-site combination as a single observation, we totalled 764 individual records, each being the average of a number of years ranging between 2 and 25.

Although all the information provided in the articles (metadata and results) was added to a general use database, data analysis focused in the five variables that appeared more recurrently in the aforementioned articles. The five variables selected were yield, pruning wood weight, yield to pruning wigth ratio (i.e., the Ravaz index), sugar concentration and pH.

Meta-analysis to evaluate suitability of rootstocks

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The calculation of Response Ratios and the construction of forest plots provided a clear overview of the general effect of each rootstock and of *Vitis* species crossing on vineyard agronomic performance. Figure 1 presents, as an example, the forest plots obtained for the different *Vitis sp*. crossings considered. In this regard, *V. berlandieri* x *V. riparia* crosses resulted in higher yields than average, whereas *V. berlandieri* x *V. vinifera* showed lower values. Concerning vegetative growth, those crosses including *V. berlandieri* generated less pruning weight, while *V. berlandieri* x *V. rupestris* and *V. rupestris* showed greater vegetative development. Last, concerning sugar concentration, both *V. berlandieri* x *V. rupestris* and *V. riparia* x *V. rupestris* crossings showed higher sugar concentration, while *V. berlandieri* x *V. riparia* and *V. Berlandieri* x *V. vinifera* presented lower values than the average.

The global analysis of the database through multivariate analysis using Principal Component Analysis (PCA) allowed the detection of several relevant trends that could be informative regarding the suitability of the different rootstocks to in terms of adaptation to future conditions. Figure 2 shows the PCA results for the comparison of some of the rootstocks that are better-known in the market. The two first components explained nearly 80 % of the variability underlying, and the scores of for each rootstock in the figure provided a global idea of their behaviour. In a context of global change, according to the global analysis of the data available, 161-49 Couderc, 41 B Millardet et de Grasset and 420 A Millardet et de Grasset provide a good behaviour, since their use results in lower sugar concentration and pH

Conclusion

The reanalysis of results from previous experiments, bringing together articles published in both peer-reviewed and transference journals proved to be a useful tool to evaluate the global implications of the use of different rootstocks.

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Tables and Figures

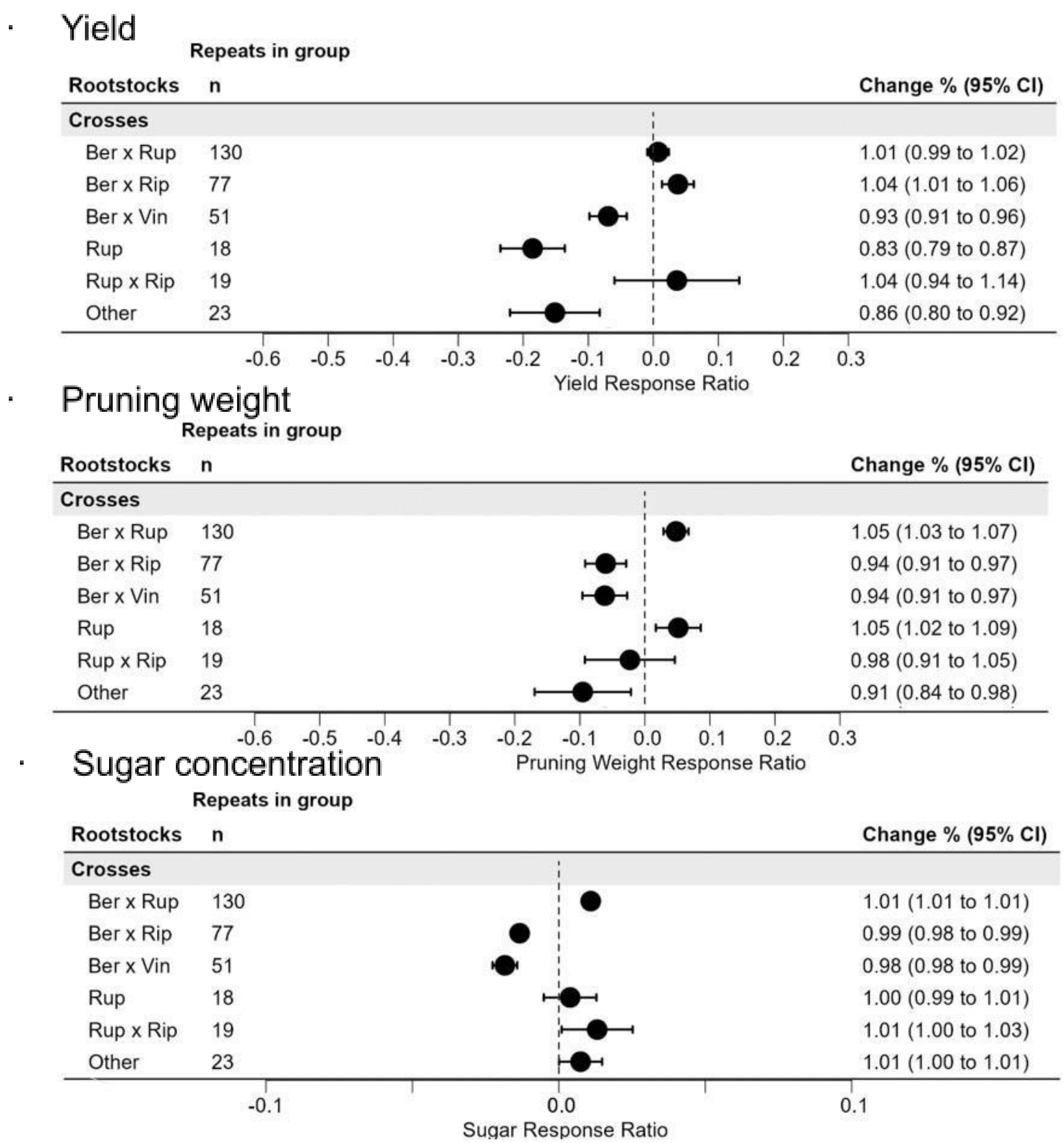

Figure 1. Forest plots showing the response ratios of the different *Vitis sp*. crosses on (a) yield, (b) pruning weight and (c) sugar content. Ber: *Vitis berlandieri*; Rup: *Vitis rupestris*, Rip: *Vitis riparia*, Vin: *Vitis vinifera*. Differences to the average are considered to be significant when the confidence interval (CI) bars do not cross the dotted vertical line.

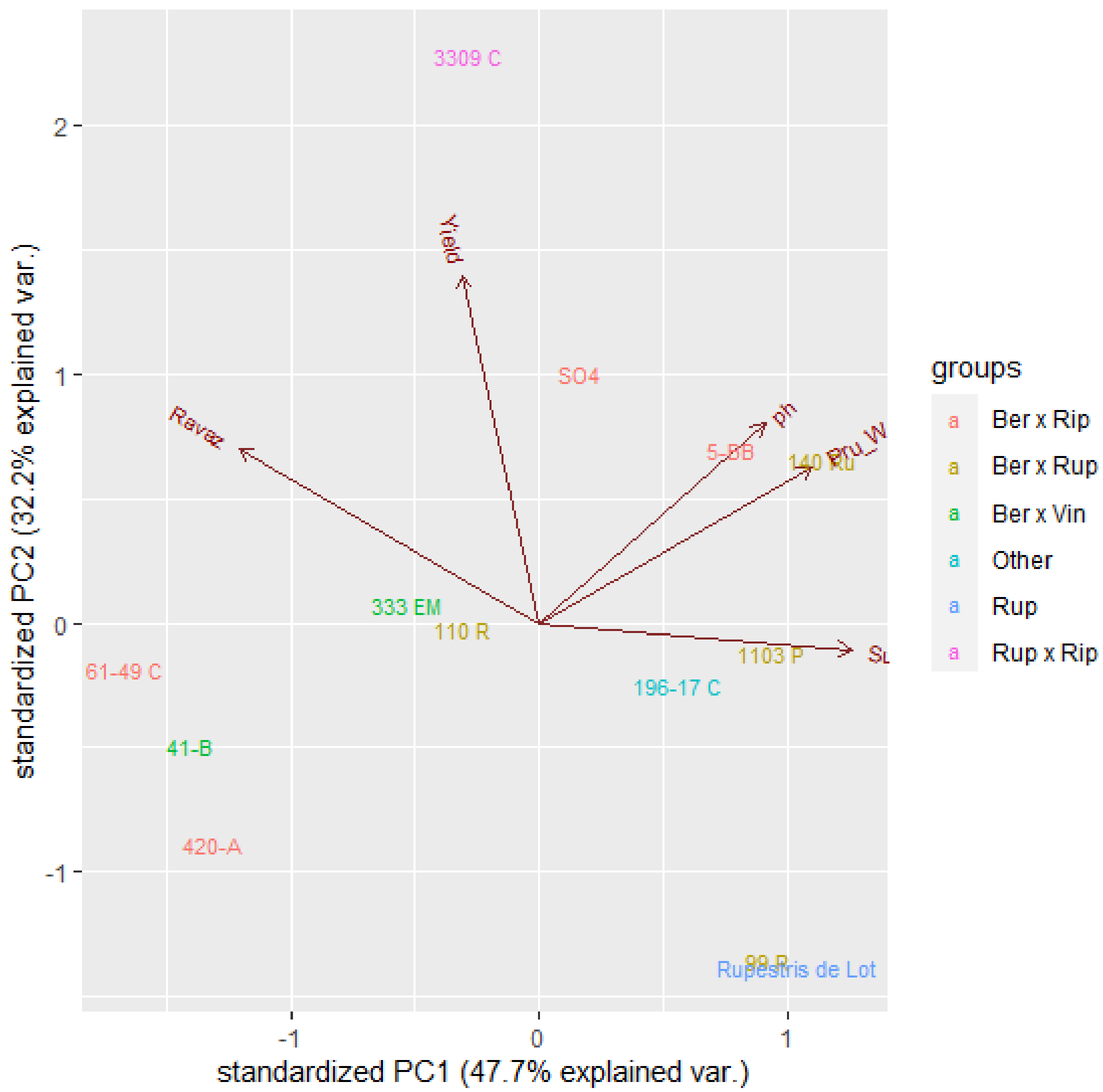

Figure 2. Principal Component Analysis of the Relative Response values for yield, pruning weight (Pru_W), yield to pruning weight ratio (IRavaz), sugar concentration (Sug) and pH for comparison of some of the rootstocks that are better-known in the market. Color codes stand for different *VItis sp.* crosses. Ber: *Vitis berlandieri*; Rup: *Vitis rupestris*, Rip: *Vitis riparia*, Vin: *Vitis vinifera*