EXTENDED ABSTRACT

# Approaches for estimating the age of old vineyards in Campo de Borja

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## ABSTRACT

Determining the age of a vineyard is essential for understanding its influence on wine quality and characteristics. Due to the uniqueness, production complexity, and perceived quality enhancement associated with "old vines," they are increasingly valued by the industry and consumers. Beyond the fact the OIV has recently released a consensus declaration of what an old vineyard is (at least 85% of the plants must be 35 years or older), in many contexts it is relevant to determine or, at least, to estimate, the age of a vineyard. In this context, the appellation Campo de Borja (Aragón, Spain) is developing a valorisation program of old vineyards that includes a scientific approach aimed at developing a probabilistic method that can allow classifying vineyards in age ranges based on objective criteria. To this end, 80 plots were selected and characterized through variables that encompassed the analysis of historical orthophotographs, vine spatial distribution in the field and vine arm structure (measuring the height and distance between pruning cuts, allowing the estimation of the average annual growth in each vineyard), and genetic fingerprinting of rootstocks and varieties.

The study showed that the temporality and quality of orthophotographs in this area are insufficient to precisely identify plots with a planting date prior to 1980. The analysis of the spatial configuration of vines in the field revealed that, since 1997, the predominant training system has been the trellis, whereas the oldest plots are planted using the goblet system, specifically the tresbolillo system, while the estimation of annual arm growth rates are around 1,7 cm in the plots of this study. Regarding genetic fingerprinting, rootstock identification was much more informative than scion's. Altogether, the combination of all the aforementioned parameters may be suitable to enable a probabilistic estimation of vineyard age.

## INTRODUCTION

The grapevine (*Vitis vinifera* L.) is a long-lived perennial plant, capable of surviving for centuries. Notably, the oldest known cultivated specimen has been documented to be over 400 years old (Vršič et al., 2011). Many European countries have a long-standing tradition of wine production. However, the introduction of phylloxera from America in the 1860s led to the devastatation of most vineyards, leading from the 1880s onward to a widespread reconstitution of European viticulture using American rootstocks (Grigg et al., 2018). In addition to phylloxera, other factors, such as viral infections, pest damage, trunk diseases, and poor vineyard management, have contributed to reducing the lifespan of commercial vineyards (Riffle et al., 2022). As a result, it is not uncommon to see vineyards uprooted only two or three decades after planting, often to be replanted with cultivars that better suit current wine market trends (Jordão et al., 2023).

In recent years, however, old vines have gained value among wine producers and consumers due to their rarity, cultivation difficulty, and perceived superior quality. The prevailing belief is that as vines age, their physiological capacity to set and mature fruit declines, potentially resulting in lower yields but more concentrated flavors (Riffle et al., 2021; Riffle et al., 2022). Consequently, there is a growing trend to recognize and preserve old vine heritage. Despite this, there is no universally accepted legal definition of an old vine. Organizations such as the Historic Vineyard Society in California and the Barossa Grape and Wine Association in Australia have set age-based criteria (Riffle et al., 2022). The International Organisation of Vine and Wine (OIV) (2024) proposes that an old vineyard must consist of at least 85% vines aged 35 years or more. Similarly, the DOP Campo de Borja Specifications Document recently introduced the category "Historic Garnachas" using the same 35 year threshold (D.O. Campo de Borja, 2024). This highlights the importance of determining, or at least estimating, the age of vineyards.

In the DOP Campo de Borja, a viticultural region established in 1980 in Zaragoza province, northeastern Spain, 6.182 hectares of vineyards are cultivated. The dominant variety is Garnacha Tinta, covering 3.300 hectares, of which 409 hectares (12.45%) are over 35 years old and distributed across 895 registered plots. However, many of these plots lack

reliable viticultural records, as formal documentation began in the 1994s. This makes it difficult to know the exact age of many vineyards, even though they likely exceed the 35 year minimum. To address this, the "Historic Garnachas Project" was proposed to the regional government of Aragón and the European Union. Its goals are to recognize, protect, and promote these old vineyards and to limit their replacement (D.O. Campo de Borja, 2024). The study includes two research lines: the Public University of Zaragoza is studying flavor characteristics of old vines, while the Public University of Navarre is developing a scientific method to estimate vineyard age in the absence of historical records. This article focuses on the viticultural aspect of the study.

## RESEARCH OBJECTIVES

The aim of this study is to develop a scientific methodology that allows for the probabilistic classification of old Garnacha Tinta vineyards into defined age ranges, particularly in cases where historical planting records are unavailable or incomplete. By identifying reliable viticultural or morphological indicators associated with vine age, this method seeks to support the objective certification of old vineyards. Ultimately, it will contribute to the recognition and valorization of wines produced from old vines within the DOP Campo de Borja.

## MATERIAL AND METHODS

This study was conducted in 12 municipalities within the DOP Campo de Borja. The vineyards are conventionally managed, dry-farmed, and trained in the traditional gobelet system. The region is characterized by a continental climate with limited precipitation and scarce water resources. For example, the average annual temperature recorded at the Ainzón meteorological station is approximately 14,5 °C, with annual precipitation levels below 400 mm. Over the past decade, the average yield has fluctuated around 4,32 kg per hectare, due to the limited availability of water resources, so it is not feasible to implement a productivity model based on maximizing yield. Instead, alternative strategies have been adopted, such as valuing the region's viticultural heritage and focusing on wine quality (D.O. Campo de Borja, 2024).

Determining the age of a vineyard can be challenging, especially in the absence of historical records. Moreover, only a small number of vineyards reach old age, resulting in a scarcity of studies addressing the factors that influence vineyard longevity. This gap highlights the need for further research in this area.

In this research, we studied different aspects:

### Assessing the plantation age and the configuration of the vineyard by ortophotos

The wineries participating in the project provided the geographical location and data of 80 vineyards, both mature and young. The first step in the analysis involved collecting aerial orthophotographs (or orthophotos). Orthophotos are aerial images of the Earth's surface that have been geometrically corrected so that the scale is uniform and free from distortions, thus allowing them to be used as accurate cartographic representations. The orthophotos employed in this study were obtained from the digital platform of the National Geographic Institute (IGN), and all of them were visualized and analyzed using QGIS, an open-source geographic information system.

A project was developed in QGIS, incorporating historical orthophotos for each municipality to enable a retrospective spatial analysis spanning from the earliest available aerial photographs (1956–1957) to the most recent orthophotos (2022). Figure 1 presents the methodology applied to one of the vineyards analyzed in the study, which enabled the estimation of an age range for each vineyard. The task proved more challenging with older orthophotos due to the exponential decrease in resolution, which often made it difficult to identify the presence of vineyards. Since the American flight ortophotos (1956-1957) were difficult to analyze, the threshold was in the Internministerial flight ortophotos (1973-1986) because they were the first with good quality and, as a result, provided the possibility to identify the existence of a vineyard. Additionally, orthophotos offer valuable information regarding the training system (such as trellis or gobelet). In the case of gobelet training, it is possible to identify the planting frame (Marco Real or Tresbolillo) and to measure the distance between vines.

### Estimating the annual growth by vine configuration

The study of vine structure was conducted in the field, where representative, well-preserved, and undamaged vines were selected, approximately five vines per vineyard. For each selected vine, the number of pruning cuts was counted, and the distance between the cuts and the total vine height were measured. This allowed for the estimation of annual growth rates across all vineyards included in the study, and consequently, an approximation of plantation age.

### Genetic fingerprinting of rootstocks and varieties

To determine the variety and rootstock identification, all selected vineyards were visited, and samples were collected from vines and rootstocks exhibiting visible ampelographic differences. Each sample was photographed and stored in cryotubes, then preserved at -80 °C in the facilities of UPNA.

DNA extraction was conducted using the commercial DNeasy Plant Pro Kit (Qiagen), following the manufacturer's instructions. The concentration of the extracted DNA was measured with a FLUOstar Omega fluorometer (BMG Labtech). Subsequently, DNA amplification was performed by multiplex PCR, targeting specific genomic regions that exhibit variability among grapevine varieties. These regions, known as microsatellites or simple sequence repeats (SSRs), are composed of short tandem repeats, typically consisting of four nucleotides. Among the various types of DNA markers, microsatellite markers (SSRs) are widely employed for grapevine varietal identification, due to their locus-specific and co-dominant nature. These characteristics enable the discrimination of both alleles at a locus, facilitating the determination of genetic relationships between different grapevine cultivars and rootstocks (Barrias et al., 2023). A total of 25 SSR markers were analyzed using three multiplex PCR reactions, which included the nine SSR markers recommended by the OIV for grapevine genotyping. The resulting SSR profiles were compared with reference data from the Vitis International Variety Catalogue (VIVC), the most extensive public SSR database, and with the UPNA genetic database from previous studies.

## RESULTS

### Assessing the plantation age and the configuration of the vineyard by ortophotos

For all vineyards analyzed (80 plots), the orthophotos were used to determine the training system employed. The predominant system observed in older vineyards was the gobelet, except in cases where winegrowers had subsequently converted the system to trellises. Additionally, around 1997, the presence of trellises began to increase the presence in the vineyards, reaching few years later the predominant in the training system in the vines plantations.

Among the vineyards trained using the gobelet system, two planting frames were identified: Tresbolillo (diagonal) and Marco Real (square). Tresbolillo was the most prevalent among the oldest vineyards analyzed. Over time, with the increased adoption of agricultural machinery, winegrowers began favoring planting frames that allowed for easier equipment access, such as Marco Real. Additionally, within the Marco Real frame, row spacing evolved significantly over the years, initially measuring 2 × 2 meters and gradually increasing to 2.5 × 2.5 meters.

For the remainder of the analyses, only plots with a plantation age greater than 45 years were considered, totaling nine vineyards (Table 1).

### Estimating the annual growth by vine configuration

After processing the field data, an average annual growth rate of 1.7 cm was obtained. By multiplying this value by the total height of the vines, the approximate age of the vineyards was estimated, as shown in Table 1. In all cases, the estimated ages closely matched those determined from the orthophotos.

### Genetic fingerprinting of rootstocks and varieties

A total of 31 samples were analyzed, including 11 grapevine varieties and 20 rootstocks. Among these, Rupestris du Lot, developed in 1879, was consistently present across all plots as the primary rootstock. Additionally, other rootstocks were identified sporadically, such as Millardet et Grasset 141A (1887), Paulsen 1103 (1900), and Ganzin 1 (1925, non-identified), which are presumed to have been introduced during the replacement of dead vines. Among the identified grapevine varieties were Muscat Blanc à Petits Grains, Jarrosuelto, Macabeo, Quiebratinajas, and Rojal Tinta, most of which were located along the edges of the vineyards.

## CONCLUSION

– In Campo de Borja, the analysis of orthophotos proves to be highly useful up to the year 1980.

– The results obtained highlight the value and reliability of studying the morphology of vine arms and pruning cuts as complementary information for identifying the oldest vineyards.

– The presence of the Rupestris du Lot rootstock provides insight into vineyard longevity, as does the occurrence of different grapevine varieties along the margins of some vineyards.

– Combining all these parameters could provide a useful probabilistic approach to estimating vineyard age.

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## TABLE AND FIGURE

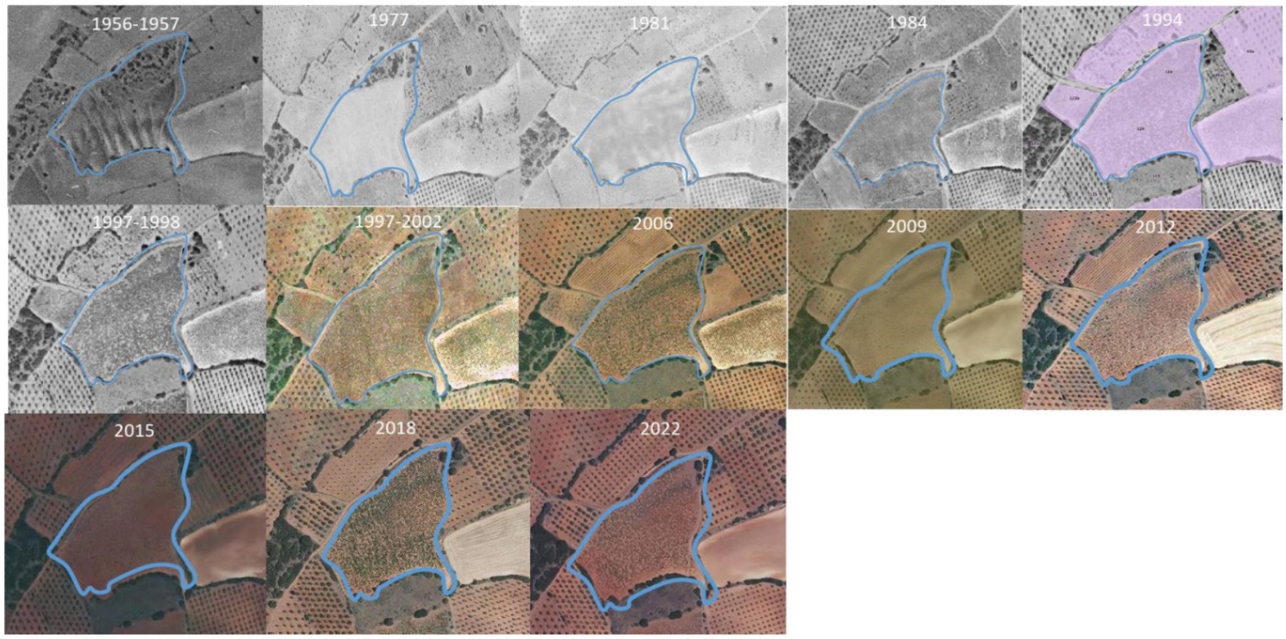


**Figure 1.** Evaluation of the ortophotos in one vineyard.

**Table 1.** Planting frame and age according to ortophotos and the age according field measurements for each vineyard.

| Municipie | Polygon | Plot | Planting frame | Age according ortophotos | Age accoring field measurements |
|---|---|---|---|---|---|
| Magallón | 41 | 57 | Marco real | >43 | 46 |
| Tabuenca | 55 | 87 | Marco real | >47 | 44 |
| Ambel | 11 | 110 | Marco real | >47 | 33 |
| Ambel | 6 | 333,334,335,001 | Marco real | >47 | 38 |
| Ambel | 6 | 35 | Tresbolillo | >47 | 34 |
| Borja | 67 | 7 | Tresbolillo | >47 | 45 |
| Borja | 67 | 8 | Marco real | >47 | 37 |
| Bulbuente | 30 | 293 | Marco real | >47 | 38 |
| Fuendejalón | 18 | 269 | Tresbolillo | >47 | 37 |