Grape ripening timing as a base for viticultural zoning: an agro-ecological approach

Période de maturation du raisin comme base du zonage viticole : une approche agro-écologique

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Abstract: Due to the central role of the ripening timing in the evaluation of the varietal response to the environmental resources, a method to manage maturation curves has been developed. The method produces an index of veraison precocity and overcomes several methodological problems, like the visual evaluation of the veraison point and the multi-annual and multi-varieties data processing. It is based on a statistical and mathematical processing of the sugar ripening curves. The index resulted satisfactory correlated with flowering time and sugar level at vintage, it allowed to study the effects of environmental resources on the timing of ripening and to classify the vineyards, and the relative land units, into homogeneous groups for what concerns precocity of veraison. For these reasons it demonstrated to be useful for zoning projects.

Key words: grapevine, ripening, zoning

Introduction

One of the main aim of a viticultural zoning is to delimitate homogeneous zones for what concerns the grape quality potential, according to a specific viniculture model, in terms of variety assortment and wine type (Vaudour, 2003). Grape quality potential is a multi-criterion concept, which may be partitioned into different indexes: technological quality (sugar and acidity), phenolic quality (anthocyanins and tannins) and aromatic quality (primary aroma compounds).
Quality descriptors are also dependent on the degree of berry physiological maturity. In particular, phenolic and aromatic quality variables are strongly influenced by the cell ripening status. In fact the extractability of anthocyanins from berry skin, and the extractability and quality of tannins from skin and seeds, are related to the degree of berry physiological ripening (De Freitas *et al*., 2000). Aroma compounds may change dramatically in the last phases of grape ripening (Coombe and McCarthy, 2000).
Phenological timing affects the onset of ripening as a result of the period of bud-break, rate in shoot growth, time of flowering and veraison. While springtime thermal course controls flowering timing, its effect on veraison date may be perturbed by the vine water status (Ojeda *et al*., 2001). Vine water status and grape thermal status play a major role in modulating the ripening process (Jackson and Lombard, 1993). Consequently, thermal status and water budget should be considered two guiding variables in viticultural zoning. These reasons strongly suggest to consider the grape ripening timing as a central issue that should be focused during a zoning process.
Unfortunately data referred to ripening timing and progress cause different methodological problems:

- date of veraison is difficult to establish by visual assessment;
- multi annual and multi location data are difficult to be statistically processed due to different sampling dates among years and sites;
- if the zoning process involves different varieties, a further problem is created by the different varietal precocity.

In this communication a method to manage data from ripening curves to obtain an agro-ecological index useful to study the varietal response to the environmental resources, with the aim to define zoning scheme, is presented. Some examples of application will be shown.

Material and methods

Data has been produced from different zoning projects in different Italian regions. As a general rule in each zone, ripening curves were built, in representative vineyards, by sampling grapes at 10-15 days interval from full veraison to harvest.

An index for veraison timing

Data processing to define an index for veraison date followed successive steps.

- Step 1 (Fig. 1A): to overcome the problem linked to the difficulty the ascertain by visual inspection the date of veraison, its replacing with the date of « full veraison » is proposed. This date may be estimated by a quadratic regression curve, which interpolates the Brix ripening curve. The date of « full veraison » can defined as the day of the year – DOY – corresponding to a specific Brix level: 12 in general. A quadratic model was preferred because it fits the physiological rate of sugar accumulation well.
- Step 2 (Fig. 1B): to overcome the problem of manage data from several years, the rescaling of the temporal axis according to « days after full veraison » (DAFV) is then made.
- Step 3 (Fig. 1C): to be able to compare data from the different years, the sugar accumulation data may be re-plotted yearly according to the appropriate quadratic regression equation, thereby moving the single point from the actual day upward or downward to the closest standard day. Standard days may defined along maturity time to be as close as possible to the actual sampling dates. The same procedure may be followed for all the other variables of the maturity curves, i.e. titratable acidity, pH, tartaric and malic acids, total anthocyanins, etc.
- Step 4 (Fig. 1D): to develop an index for veraison date, Brix data were normalized by year (possibly by variety) and by standard day via the normal score transformation $z = (x-\mu)/\sigma$. An index was then computed for each trial site as the average z score of the first post-veraison sampling dates. The index thus took into account the data of the first month of maturity so that and the sampling error may be notably reduced. The index assume positive values for vineyards early in veraison and negative values for vineyards late in veraison.

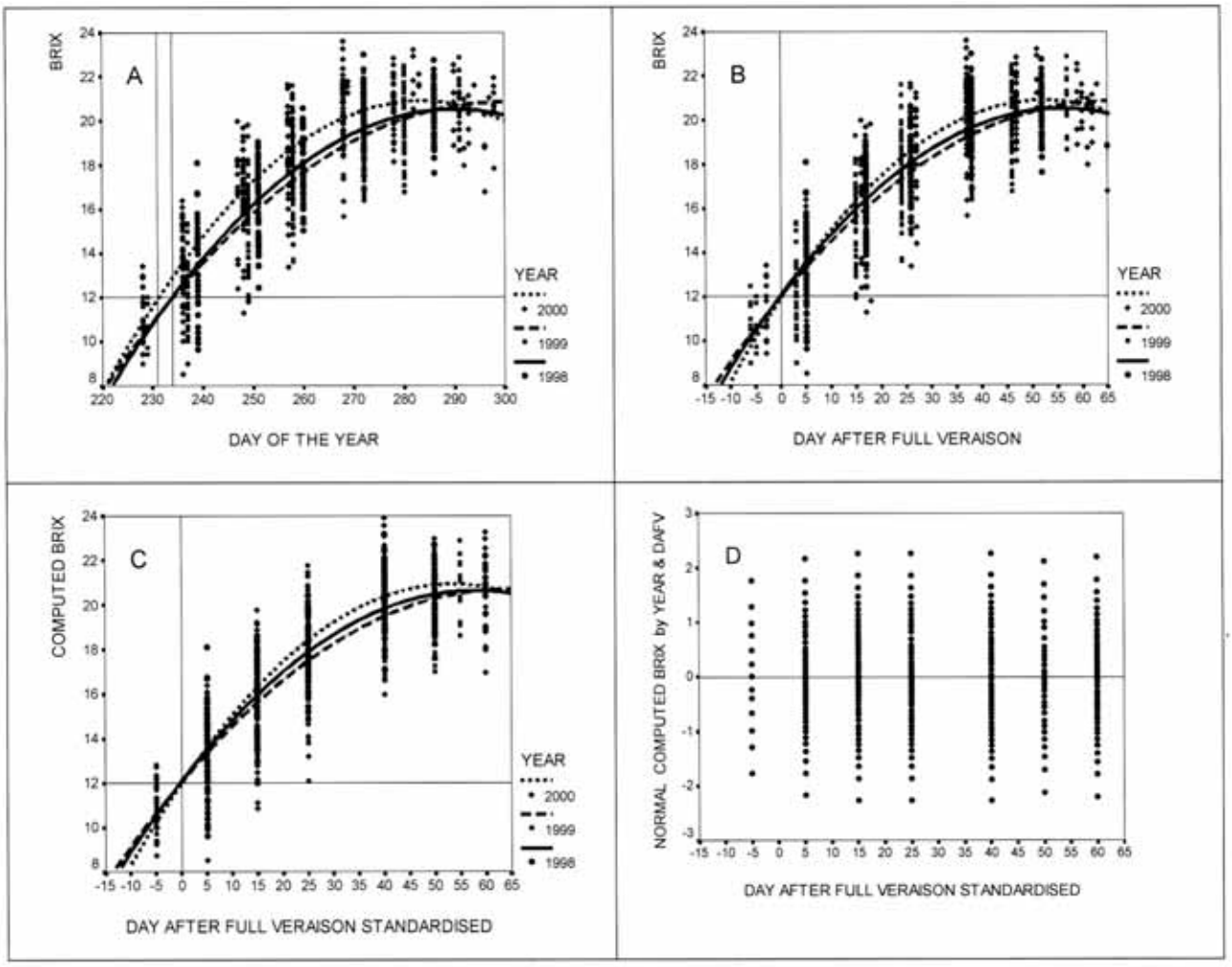

Figure 1 - Graphical representation of the four successive steps followed to develop an index for veraison date on the base of the ripening curve data (from Failla *et al.*, 2004)

Validation of the index

In general term the index of veraison date has expected to be related with the flowering date and the sugar levels a harvest. This has been verified in different zoning projects (Fig. 2). The correlations resulted enough high to show a consistency of the index. However, as later will be discussed, the residual variability of the index show that specific factors may affect the veraison date independently by the previous phenological timing and that the technological maturity is not only affected by the timing of veraison.

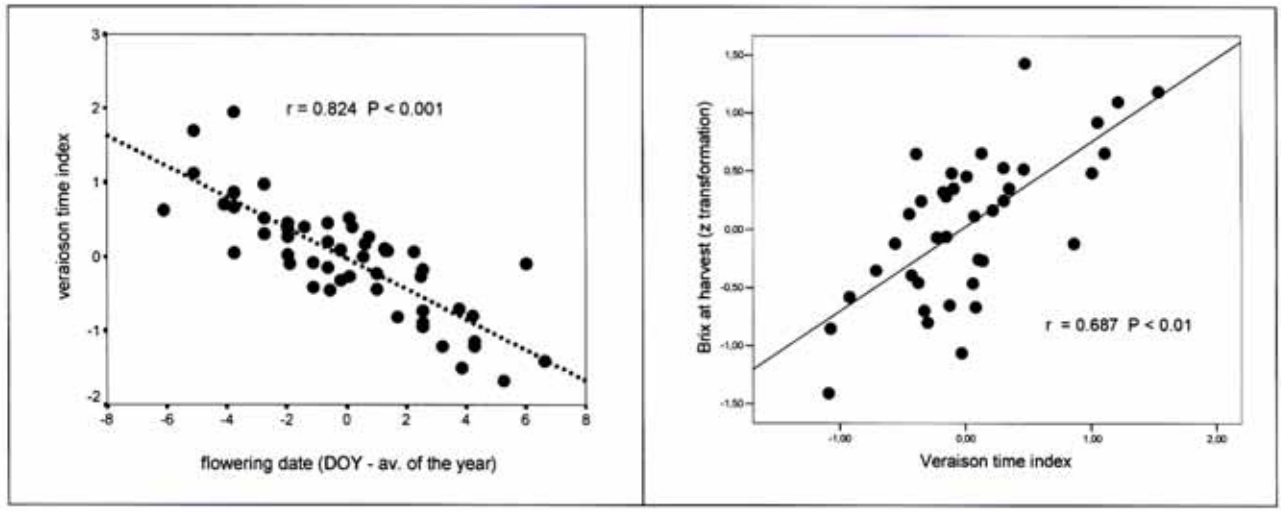

Figure 2 - Regression between veraison time index versus flowering data in Valtellina – northwestern Italy (left, from Failla *et al.*, 2004) and Brix at harvest in Collio – northeastern Italy (right).

Results and discussion

Application of the index

The index has been applied in several zoning projects as key variable to classify vineyards according to their precocity of veraison. Moreover relationships among precocity of veraison and environmental resources were studied by correlation and general linear model methods.

Application in an Alpine environment (Valtellina)

Running east-west in the center of the Alps (Lombardy, northern Italy), Valtellina is the upper valley of the Adda River, an important left tributary of the Po River. Its southern slopes have long been devoted to viticulture, with the vineyard belt extending from 300 to 700 m a.s.l. over nearly 70 km in a district whose morphology has been radically altered by artificial terraces. Vineyards now occupy about 1,200 ha. Nebbiolo, is the most widely grown cultivar, it is a late ripening red variety able to give wines of high vigor and longevity. Climate, soil and vineyard performance were characterized to develop an eco-physiological model for zoning the district's viticultural aptitude. Based on a representative sample of 54 small, steep-sloped terraced vineyards planted with Nebbiolo, the model included three-year (1998-2000) data sets for phenology, maturity curves, yield, vigor, and grape assays, with appropriate indices to manage these sets. Soils were characterized by pedological description and climate by both annual values of potential photosynthetically active radiation (PPAR) and estimated thermal fields expressed as growing degree days (GDDs) on base 10°C; PPAR ranged from 2700 to 3200 MJ $m^{-2}year^{-1}$ and GDDs from 1100 to 1800. Vineyards showed a 12-day range in phenological timings, with early sites showing the highest technological maturity and medium sites the highest phenolic maturity. Elevation and PPAR were the main environmental factors affecting vine budbreak, bloom date and veraison precocity, estimated by the veraison time index (Fig. 3).

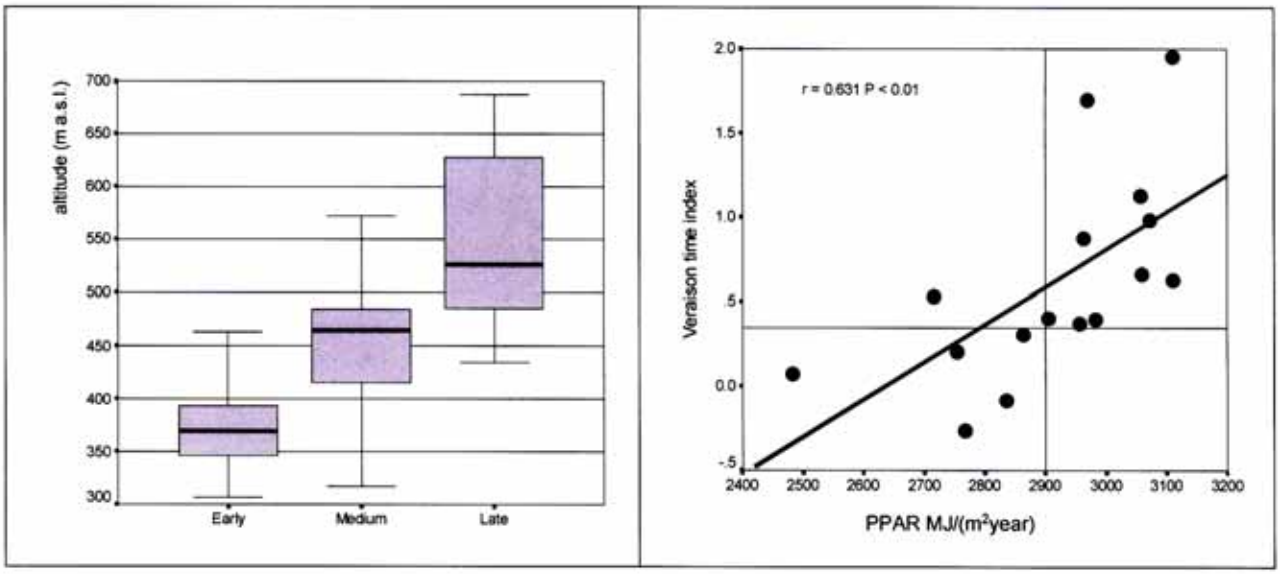

Figure 3 - Valtellina zoning. Frequency distribution of the elevation level of the reference vineyards, grouped in relation of the veraison time index (left). Regression between veraison time index versus potential photosynthetically active radiation (PPAR) at the lower elevation (right). (From Failla *et al.*, 2004)

Application in an Apennine environment (Oltrepò pavese)

Oltrepò Pavese is a hilly area of Lombardy, a region located in northern Italy with a vineyard surface of approximately 15.000 ha. It represents the widest viticultural area of all the region and one of the most extended zones of Origin's Denomination of all the country. The mainly grown varieties, also from the historical point of view, are the local *Barbera* and *Croatina* used for the production of the red wine Oltrepò and the international *Pinot noir* used for the sparkling wine.

For the viticultural zoning of the area, climate, soils, viticulture and enological properties have been characterised with the aim to select zones adapted to produce a modern style premium red wine based on *Barbera* and *Croatina* grapes, and sparkling *Pinot noir* wines. For the viticultural survey, 80 trial sites, representative of the soil, climate and agronomic conditions have been chosen. In all the sites for three years (1999-2001) grapevine yield, vegetative growth, maturation curves and must composition were detected.

By a statistical data processing of the three years maturation curves, it was possible, thanks to the veraison time index, to subdivide the vineyards in four precocity classes (Fig. 4 left) and to study the environmental factors affecting precocity and grape ripening. For *Croatina* and *Barbera*, the mainly influencing factors regarding the precocity resulted to be soil texture and depth, site elevation, slope orientation and PPAR (potential photosynthetically active radiation) availability (Fig. 4 right), while for *Pinot noir* altitude and soil texture played the most important role.

Application in an hilly pre-alpine environment (Collio)

Collio is a small viticultural area in Gorizia province (north-eastern Italy), where a wide varietal assortment is allowed to produce Control Denomination of Origin wines. Few local varieties (*Tocai*, *Ribolla gialla*, *Picolit*, *Malvasia istriana*, *Riesling italico*) are fighting with several international varieties (*Chardonnay*, *Pinot blanc*, *Pinot gris*, *Pinot noir*, *Rhein Riesling*, *Sauvignon*, *Traminer*, *Cabernet sauvignon*, *Cabernet franc* and *Merlot*) for new vineyards. A three year survey aimed to study the variety response of two local varieties (*Tocai* and *Ribolla*) and three international ones (*Pinot gris*, *Merlot* and *Cabernet sauvignon*) in a range of experimental plots, representative of the different soil and climatic conditions, allowed to assess the diverse land suitability both for local and international varieties. Collio was characterised for landscape and soil variability. Forty seven land units were delimited from the alluvial and colluvial soils up to the high steeply hilly slopes. Climate analysis of the area showed in particular a strong gradient in annual rainfall with a difference of more than 300 mm (from 1300 to more 1600 mm per year) in a very small distance. The gradient in rainfall and the different soil water capability, determined a different intensity and length of the summer period during which vineyards undergo to a mild water deficit. On these bases, an ecological index has been developed in term of length of the period, in days, during which soils have depleted the water reserve between field capacity and -0.1 MPa. On the other hand, data from the ripening curves allowed

classifying the sites according to the timing of veraison estimated by the precocity index. So, taking into account soils, climate and timing of veraison by statistical data processing, precocity of veraison resulted in relation to the site elevation and to the water deficit index with a contrasting effect: higher elevation later veraison; higher water deficit earlier veraison (Fig. 5)

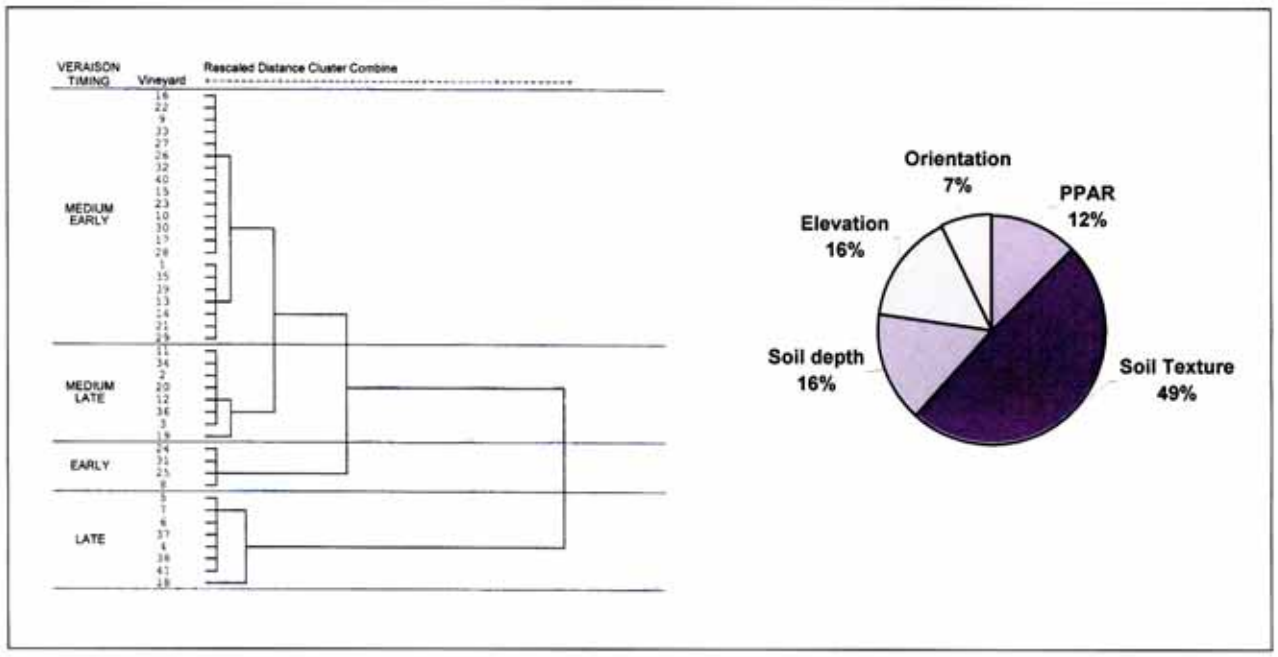

Figure 4 – Dendrogram grouping selected Croatina vineyards in Oltrepò pavese according to their veraison time index (left) and estimation of environmental effects on veraison timing according to expected variance components based on a general linear model (right).

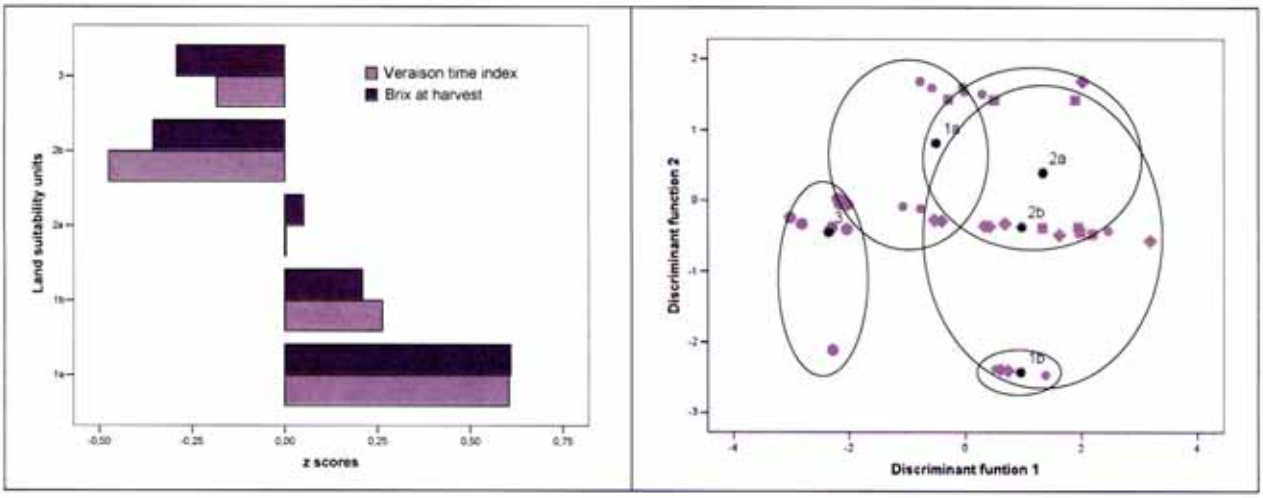

Figure 5 - Classification of groups of land units according to the veraison time index and the Brix levels at vintage (left) and validation of the classification by discriminant analysis based on agro-meteorological data (right).

Conclusion

In order to proceed for a viticultural zoning, one of the most relevant methodological problem is connected to the choice of the mainly important viticultural variables, able to guide the zoning process, toward the classification of the vineyards into different suitability groups. In general, the level of technological ripening is used for these purposes, even if this choice does not seem always the best solution. In fact, according to

the different time of vintage, vineyards located in different environmental conditions may be able reach similar technological ripening degree. Moreover, as a consequence of the different thermal courses, phenolic and aromatic ripening degree could be very different, according the onset and the duration of the ripening processes. To overcome this methodological issue, we suggest using the ripening curve timings, together with the ripening degree, as a key agro-ecological variable to guide a zoning process.
In the present communication, the method to statistically manage data from ripening curves, collected in different years and from different varieties, is illustrated, with the aim to obtain a numerical index for veraison time. The proposed index demonstrated to be correlated with the vine phenological records and the grape ripening degree. It confirmed its capacity to easily classify vineyards according to their veraison precocity, and to effectively study the environmental factors affecting veraison timing. Its use, associated with data from ripening degree, proved to be adapted for vineyard classification for viticultural zoning.

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