Sustainable Viticulture: Current Practices and Future Developments

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SUMMARY

Since ancient times, viticulture has been developing in two opposite trends: quality and quantity. The origin of this paradox can be found in the Greek and Roman period and raises from the interaction between technical and cultural factors. Rather fertile grape varieties conducted on high training system have been chosen for high yield in suitable productive areas. In opposite parsimonious varieties together with lower training systems were used in more difficult environments.

The dualism between productivity and quality which marked the history, the traditions and the customs of different regions has hardly been able to find a positive evolution, just because of this combination of social factors.

In the next ten years, viticulture will not be very different from today's one and it is very likely that the economic models will be more and more oriented toward the valorisation of terroir (Europe) or the emphasis on variety (New World). In the first case, the vineyard and the wine are part of a system trying to keep in balance social, environmental and economical components. When the protagonist is the grape variety, there is a much more simple and clearer message for the consumer; in this case the reputation of some noble varieties open new markets.

Grapegrowing, winemaking and wine marketing are becoming more and more part of the same and complete concept.

The grape growing techniques which have been dominating the last 50 years (soil cultivation, fertilisation, irrigation, etc...) have favoured an augmentation of the vigour with direct effect on the enological quality of grape and overall on the plant perenniality which has been dramatically reduced. World-wide a worrying increase of vine diseases (especially wood diseases) is also observed.

Better balance between vegetation and production should be found with a better plant management (i.e. less and better wound on the plant). Soil also should be regarded with more attention to avoid further lost in production capacity, erosion problems, pollution with alien molecules, destruction of the structure or damage to the biomassa balance. Pest control will have to enter deeper into an integrated management of the vineyard with better attention toward the secondary effects on humans and environment.

To progress however, it is necessary to improve the agronomic knowledge and general understanding of viticulture and it's environment.

KEY WORDS

viticulture, terroir, economic model, sustainable

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WINE AND VINEYARD STORY INTERPRETATION

The presence of ampeloďdei is demonstrated by the fossils discovered in many areas, but the use of grapes for making wine is – very likely - the responsibility of the Etruscans (Phoenix) who discovered it between the VII and V century B.C. It was a Mediterranean civilization where man learned to ferment grapes to produce a rare, important and religious drink. The Greeks too exported this knowledge to South Italy while the Roman diffused a practical and extensive winemaking where quantity was more important than quality.

Viticulture and its development oscillated between two opposite tendencies:

- Quantitative
- Qualitative

These choices were not only result of human ideals but resulted from the interconnected very important cultivation facts: environment and grape varieties.

In the Mediterranean basin cultivation is hard and therefore valuation of the crop is necessary. In the Tyrrhenian area or in the Po valley, conditions are much better for plant growth. The result is the widespread use of smaller vine training systems in the former area and use of larger systems in the latter (vines grown on trees and pergolas).The similar effect occurred in the selection of varieties to be propagated: more frugal in the former and more fertile and luxuriant in the later.

Columella (a Roman author) recommended to take the "maxime fertiles" (most fertile) varieties for propagation. In the southern Italian peninsula the traditional cultivation of Greco and Aglianico became common whereas in the north it was the Trebbiani family of vines; briefly, two cultures methods were involved: the Magna–Grecia and the Etrurian–Roman systems (20).

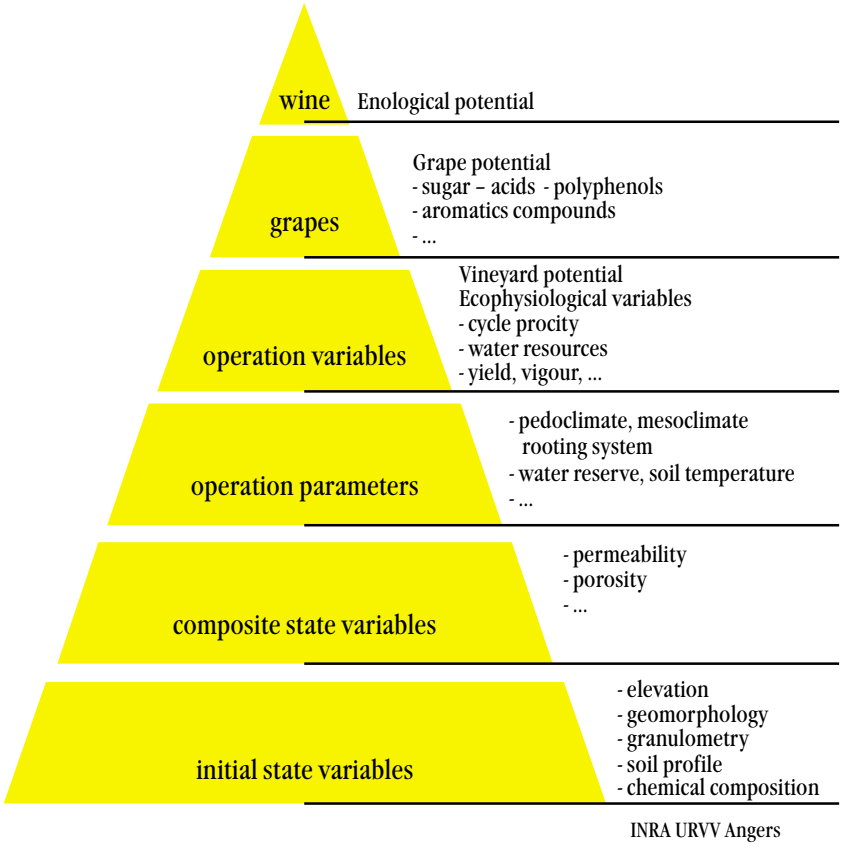
The two systems, one with small production, limited varieties and enhancement of the quality of the choice and noble wines for discriminating consumers. In the other system there are good conditions for intense and productive cultivation that favour popularisation of the higher consumption with loss of quality for the product (4).

With the Etruscan and Roman system we face the conceptual transformation of the wine image. These are the roots of the dualism between productivity and quality that helped to establish the tradition. It should be remembered that the Romans distinguished between "merum" and "vinum", the first one being pure while the second one was mixed with water).

VITICULTURE MODELS

Viticultural choices and their economic development

It is clear that we can distinguish two different models: one that emphasises the name of the cultivation area and the other that concentrates on the grape variety.



The first one is historically connected to many European names with different expression. More recently it became the subject of many researches like the OIV's "Viticole Zonation" programme and has therefore became a worldwide development (21).

But, in Europe too, there is improved and more careful consideration of the central importance of grape varieties and their good use. Many initiatives have been made to show the value of varieties and suggest improvements of their use. This caused the search for ancient, almost abandoned, varieties (24, 33, 39, 44, 46, 48).

Wine and territorium expression

In the recent past and sometimes still today in the vineyard there have been many researches conducted on production factors (canopy management, fertilisation, water resources, soil management, pest control ...). In the present time, economic factors are getting more and more important. This attitude contrast with the economy devoted to the search for a typical product and to the development of the product image wile a decrease of consumption is also evident.

The aim is to co-ordinate the cultivation techniques with the physiology of grape ripening in order to achieve the best possible grape potential. The current growing trends are affected by an economic system where wine is central with improvements achieved by choice of suitable environments, agronomical qualities, urbanistic structures, architectural resources, landscape, viability and economical and cultural exchanges.

The territorium represents a population of environmental conditions rather complex in biological and other resources. This is characterised by fixed components (geological substrate, climate, exposition...) but also by others factors that might be modified by farming techniques (32). The territorium influences wine quality and character but only if grape quantity is reasonable for an acceptable dilution of berry compounds (1, 13).

The quality and characteristics of the wine results from a group of factors.

The territorium effect on the vineyard is due specifically to earliness, vegetative expression, must composition and taste of the product (1, 35).

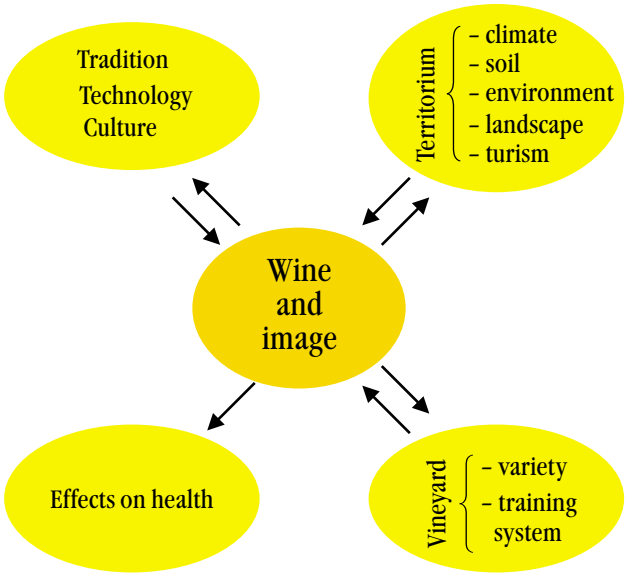
e.g. anthocyanin and acids synthesis, maturation kinetics, skin and seed polyphenols production.

e.g. if tannin extracted during vinification comes mostly from immature seeds it indicate a late-ripening terroir.

The management of territorium effects

The knowledge of territorium allows advice to vine grower and wine makers to be more precise to determine and reach their overall goal. With a similar enological potential, we can observe a difference of tipicity for the wines obtained. This will encourage the vine grower to take into consideration more or less completely the reaction and interactions of territorium and grapes. The target is still to use the best grape variety possible in order to obtain the best wine possible. But on a larger scale, the territorium is a social and cultural matter that maintains over time the image of its origin. The viticultural environments are agricultural places like many others, but they have to achieve their value through a plant and human know-how (1).

In the traditional function of agriculture as it affect environmental resources, countryside social issues and valuation of territorium or landscapes are becoming more important. The vine grower's activities affect important aspects of territorium management. We can observe that production quality in the last few decades stayed confined in sectors and has not developed in the global and interdisciplinary way that is nowadays essential.



The present wine systems are therefore descended from vineyard systems that worked in harmony with the environment in to global economy but were sustainable for the territorium.

INTEGRATED PLANT PROTECTION

Guidelines for integrated production of grapes

Integrated Production of grapes emphasises the following objectives (27):

- To promote viticulture that respects the environment, is economically viable, and sustains the multiple functions of agriculture, namely its social, cultural ad recreational aspects;
- To secure a sustainable production of healthy grapes of high quality and with a minimum occurrence of pesticide residues;

- To protect the farmer's health while handling agrochemicals;
- To promote and maintain a high biological diversity in the ecosystem of vineyard and in surrounding areas;
- To give priority to the use of natural regulating mechanisms;
- To preserve and promote long term soil fertility and vine longevity
- To minimise pollution of water, soil and air.

Successful Integrated Production requires professional, up-to-date training and a positve and sympathetic attitude to its aims.

An important aim and requirement of Integrated Production in viticulture is the conservation of the vineyard environment, its habitats and wildlife. They must not be detrimentally altered or polluted.

For new vineyards, site, rootstocks, cultivar, planting systems must be selected and harmonised so that regular yields of quality grapes, and hence economic success, can be expected with a minimum use of agrochemicals and environmentally hazardous practices. Frost pockets and poor drainage situations must be avoided. Cultivars and clones resistant to diseases and/or pests as well as a diversification of cultivars and rootstocks are recommended. Planting material should be sound and certified as virus-tested. Where this is not available then planting material of the highest health status available must be used. Narrow planting systems must be avoided whenever possible as they require, in most cases, soil management practises that are in contradiction to the aims of IP (e.g. total surface application of herbicides).

The structure, depth, fertility, fauna and micro-flora of the soil must be conserved and nutrients and organic matter recycled where possible. Restricted quantities of fertilisers consistent with high grape quality, plant health and the mineral and organic nutrient reserves in the soil may only be used if chemical analysis of soil or plant material shows they are justified. Ground water pollution with fertilisers, especially nitrates, must be avoided.

The aim of establishing alleyways with cover plants is to avoid soil erosion and compaction without detriment to yield and quality, to maintain and enhance plant species diversity in the vineyard to increase ecological stability, and to minimise the use of herbicides

Indirect plant protection measures

These indirect measures (=prevention) must be listed in the guidelines and the growers stimulated to use them to the fullest extent (e.g. resistant clones and cultivars, appropriate choice of planting and training systems when planning new plantations; avoidance of excessive nitrogen, proper canopy management to reduce diseases and pest impact, green cover to replace herbicides and to enhance biodiversity within the vineyard at the botanical and faunistic level; the protection and augmentation of natural enemies).

At least **two key natural enemies** (one of them usually a Phytoseiid mite, the second one representing important insect parasitoids or predators) must be identified in regional guidelines and their protection and augmentation be declared important. Where Phytoseiid predators are absent from vineyards, they must be introduced where the pest situation (e.g. spider mites, thrips) requires regular control measures).

Populations of pests and diseases must be regularly monitored and recorded. Scientifically established assessment methods appropriate to the region or locality must be used. For each pest or disease the approximate level of infestation or the risk of damage must be estimated.

Where the use of plant protection products is necessary, the product selected must be the least hazardous to humans, livestock and the environment whilst providing effective control of the pest, disease or weed problem.

Spraying equipment and spraying conditions minimising the health risk of the operator and drift should be preferred. Spraying in windy conditions is not permitted.

Sprayers must be calibrated at the beginning of each season and their proper functioning should be checked before each treatment.

THE REDISCOVERY OF GRAPE VARIETY

Commercial competitiveness, the development of an image, the search for tipicity contributed to recognition of the importance of the variety (2, 3, 9, 14, 23, 31, 35, 47). Next to the international varieties, the search for local qualitative varieties is becoming more common thanks to research and trials done in many different environments.

The tendency is to increase the production of red wine but there is also an obviously improving base for white wine.

In several areas but overall in Italy, there is growing interest in the use of interesting local varieties which can also avoid a possible worldwide, though high level, standardization (4, 24, 33, 39, 44, 46). Many are the examples and we could mention Arneis, Fiano, Falanghina and Verdicchio for whites and Aglianico, Primitivo, Nero d'Avola, Negro Amero and Refoschi for reds.

The remarkable work of variety selection allowed selection of biotypes free from degenerations. In particular, mass-selection has the advantage of giving more heterogeneous material but without a guarantee of health. Vine growers still have the right to make their own selection and hopefully it will last for a long

time. The selection of clones is, as main advantage, ensuring healthy plant, but it is well know that they do not have the diversity and therefore genetic complexity of mass-selected varieties (13, 30, 40). A single clone cannot produce a complete wine and therefore it becomes essential to put many clones in a single vineyard. It is quite probable that in the near future selection will manly go towards population standards in order to guarantee a better balance regarding pathological problems and to maintain the complexity that as is part of the wine story.

CULTIVATION FACTORS

The soil, the subsoil and the vineyard soil management

In order to produce great wines, there is no one geological formation that is better than another. On a world wide level, many famous vineyards are planted over calcareous mother rocks and calcium is known to have a positive effect on soil structure. There are still many questions for geological science to address. Thanks to many praiseworthy researches it can be said that great soils for vineyards respond to standards of natural and regular hydrological conditions that have at least as much importance as the underlying geological structure of the place.

In contrast, more humbles soils, depending upon the year, now easily develop excess or lakes of water. It is mainly in bad years that the superiority of great vineyard soil is obvious. Overall, this is because of the quality of their well structured soil, with good permeability and air availability (1).

The soil capacity, even in the best situations might be put into difficulties mostly reason of two kinds of factors: soil erosion and soil compaction (consolidation). For a few decades now, mechanisation has become continually more important in all vineyard management, with evident economical advantages. However, sometimes, soil cultivation and passage with machines, in whatever climatic conditions, especially humid, has certainly favoured compaction. In the long run, the structure is damaged and this gives rise to erosion.

Search for the conservation of the whole soil function and capacity is luckily much more developed today even if there is still a long way to go. There is only very little work done on erosion on hills, but results are worrying (12).

It is fundamental to protect the vineyard soil since it is a capital element that cannot be replaced and is indispensable for the originality, the characteristic and the economy of the territorium.

With such aims, during the last two decades several techniques have been developed to protect with grass or mulch, in order to avoid erosion and improve the nutritional status, as well as sanitary aspects and also to obtain improvements in the wine (12, 36).

Much work has been done in all viticulture environments across a range of different conditions. All this work certainly created an improving recognition on how to produce good wine and, at the same time, to conserve the soil as an issue not to be avoided.

Vineyard fertilisation

After decades of important fertiliser use, during the last 20 years use has been partly reduced because of changes in consumer preferences. Growers are moving toward a production system where wine is the true element of concern. Nutrition choices are becoming more in harmony with the soil and the plant for a more rational answer and one also closer to the optimum for other effects such as pathology (6, 7, 10).

Besides a well fertilised viticulture thought to produce good yield, there is clear evidence of a viticulture producing great wines coming from slightly suffering vineyards. Great attention is paid to the soil balance, with its microbiological balance (mycorrhizae as well) that contributes to the territorium value and the fame of its wine (34). Unfortunately many soils even in famous areas now have serious problems because of inappropriate use and the conservation of their capacity is seriously in danger. A further worry is the accumulation in the soil of alien molecules, especially copper and other heavy metals. In the near future we will have to engage in finding solutions more adapted to sustainable production and long lasting soil capacity.

The rootstocks varieties

The rootstock is an important factor of plant vigour and therefore has much influence on production and wine quality. Knowledge on rootstocks varieties has greatly improved and we should note an important growth of the Berlandier x Riparia group (mainly Kober 5BB, SO4) for the obvious advantage of quick fructification. The most obvious problem is that the longevity of vineyard is often reduced. There are problems of grafting affinity between the rootstocks and grape variety. There is often a great difference of diameter between rootstock and scion and that does not favour good plant nutrition and regular growth. It would be certainly interesting to consider combinations such as Berlandieri X Rupestris (Paulsen, Richter or Ruggeri), Vinifera x Berlandieri (41B, Fercal), Riparia x Rupestris x Berlandieri (Gravensac, Prosperi) or also Cordifolia x Riparia x Rupestris (44-53 Malčgue). It is realistic to think that in the near future there will be a big change in the choice of rootstocks. There should anyway be more attention given to affinity, regular growth of trunk, vegetative-productive balance and interaction capacity with soil (15).

The rootstock is not so important for the determination of the quantitative-qualitative result, but more to determine the vegetative-productive behaviour as well as vineyard longevity. Therefore it is a fundamen-

tal tool to organise the strategic goals of a vineyard economy.

Grape growing techniques

In the last 50 years the specialisation process has been the basis of important modifications everywhere including Italian vineyard. Commercial evolution of the sector favoured fundamental replanting in the most traditional zones. That caused profound changes and from polycultural estates 3 types of estates were derived: specialised vine growing estates, partly viticultural estates and estates with marginal viticulture. Those profound changes (Lozato Joutard J.P.) are typical of quality vineyards and we can declare that the process is in a phase of completion (29).

Growing system

This can be separated into two main systems: an extensive one typical of the fertile areas and the other one of reduced dimension, to be found in difficult environments.

Research on growing systems, during the last decade was directed to foliage function, and leaf efficiency (SFT, SFE). Apart from canopy management (5, 25, 26, 43) these studies have suggested some indices (number of leaf layer, total and exposed leaf superficies, exposed leaf superficies and production...) with the purpose of determining the best vegetative-productive balance (22).

Successively, many studies tried to take into account leaf efficiencies in relation to cultivation or environmental factors (CO_2 analysis, transpiration, fluorimetry, ...) (37). This permitted a better canopy management and helped to develop formation and production pruning, in order to adapt the growing system and improve the photosynthetic efficiency (38, 42).

Taking into account the absolute need for quality improvement as well as the need to control production costs, modern growing systems are almost all based on cordon with short pruning for integral mechanisation of pruning and harvesting.

However it cannot be generalised because many viticultures would not be easily adapted in this direction for obvious reasons like for varieties with low fertility on basal buds, topographical difficulties, low productions or enological constraints.

Pruning

The vine, by nature, is a climbing liana with a desordinated vegetation and irregular fructification. Since ancient time man controlled the plant by pruning with the aim of regulating the production, as well as the goodness of grapes. The objective was to bring the plant to a form and dimension adapted to its environment and to the economy of vine growing.

Pruning, intended as the elimination of dry or green parts, including grapes, is the best way to improve the balance between roots and vegetative parts with the purpose of regulating plant growth and production. Pruning has also to fulfil another fundamental aim: the conservation of capillary total function. As the vine is distinguished from other plants by its inability to heal its wounds, it is important to remember that each cut creates a wound that will never close but develop toward necrosis; more importantly it might more or less obstruct sap circulation. So, in order to have plant that will survive, it is important to make cut in the proper way, to avoid necrosis that would threaten plant's survival (28). Dry pruning has to be replaced by green pruning which would be the real choice for renewal without creating permanent wounds.

In last few decades, ability in pruning has reduced. and overall has received an attention largely below its importance. The mechanisation also contributed to the rise of problems of different kinds but mainly wood diseases that endangers plant survival.

It is important to come back to a better understanding of pruning and agricultural practice that is the basis for long lasting plants and quality of production.

THE KEY OF THE SYSTEM

Vigour and vineyard duration

Technological progress and major efforts on to the vineyards during the last few decades has resulted in improved vigour and production potential. It is well know that an excess of vigour can compromise the quality potential of grape (41). Vigour management is currently one of the major problems that is not simple to solve due to poor understanding of the physiological mechanisms involved. The factors involved are various: rootstock variety, clone selection, soil preparation before planting, fertilisation, pest control and soil management. Fertiliser content (especially nitrogen) and soil management are however slightly more effective on the vegetative-productive balance.

Early senescence of vines is now a world wide problem and investigation should be made into the most important predisposing factors should be done. Among them is high yield, bad pruning with excess wounding, lake of plant reserves (starch), wood diseases and degradation of soil structure.

The development of new techniques has an impact on the vineyards and the wine economy, as well as on the wealth created. The economy always needs innovation but the vine grower has to be able to adapt this to the quality of the product and the longevity of the vineyard and of the territorium.

Maturation and harvest date

"All that was done in the vineyard was called work except the harvest, which was the gain of the year" (C. Pégny).

In earlier times, the decision to harvest was regulated, and in some French and Italian regions, up to a

recent time, it was also necessary to monitor the ripeness.

To decide when to start harvesting is never easy: there is of course the growers impatience but also the difficulty of obtaining all favourable conditions for harvest, due to many disturbing factors such as drought, violent storms, light or hard rain but especially extended rain. By planning the harvest well, growers can dramatically improve the grape quality: it requires careful observation and a little bit of luck (8).

In the berry the physiology of maturation is completed when sugar derived only from photosynthesis reaches its maximum and this does not necessarily correspond to the physiological maturation of the seeds.

The technical maturation is the best moment to harvest for some types of wine.

It is clearly more difficult to solve the problem of optimum grape quality when the wines are made from only one variety instead of a blend of several. Probably the main problem is difference that might occur between optimum sugar level and quantity of other constituents like aromas and polyphenols (16, 17, 19). As for example in the Moscato bianco (11) where sugar and terpenes synthesis are quite independent. This depend also much on environmental conditions (temperature, soil) and cultivation techniques.

When withering starts, linalool is the most affected (diminution) of the free alcohols while the terpenes components shows a slight increase (16, 18).

For red wine it has been demonstrated that environmental factors have a greater effect on flavane polyphenols than on sugar synthesis (7). Furthermore, the difference between grape varieties in the accumulation potential is very variable; as for example in sugar accumulation Barbera has a high, Prosecco a low and Cabernet Sauvignon a middle potential.

In more recent researches was demonstrated (45) how the berry composition for a defined variety at a precise moment depended on the seed number. For the juice, the sugar content diminished with the augmentation of seed number while no difference was observed for tartaric acid. Polyphenols indices in the skin increased with the increase of seed number per berry indicating the relation between seeds and anthocyanin and flavan synthesis.

THE TWO VITICULTURES

In every vine growing area there is a viticulture in search of the maximum of production allowed by the local conditions and another that takes advantage of the originality of its grape varieties in a well defined territorium.

Those two viticultures, use the variety, the agronomical techniques and the environment differently. On fertile soil high vigour, expanded growing system, generous pruning and low planting density; on difficult soil, fine varieties, reduced vigour, limited pruning and middle-high planting density.

As a result there are at least two systems of cultivation: one for lower quality and the other for higher quality wine. It is probably because of confusion on the importance of this choice that many problems have arisen.

Nowadays for a viticulture orientated toward the quality of wine but also good management of the territorium it comes from, it is crucial to manage cultivation techniques which are based on knowledge and on the possibilities that characterise each period.

The future of profitable viticulture disregarding quality is uncertain. In the same way the exclusive search for quality might be rather utopian but the only justification for its consummation might well be its good quality.

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