Interaction between fertilization and mechanical winter pruning of grapevine. Effects on plants yield and grape composition.

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Abstract

This work aimed to understand how the interaction between mechanical pruning (MEC) and organic fertilization of the vine with municipal solid waste compost (MSW) can bring benefits from the productive point of view in terms of yield and quality of grapes and vegetative growth of the plant. The study was carried out at Quinta do Gradil, Vilar, Cadaval, in the wine region of Lisbon, in a Sauvignon Blanc vineyard, in a strip-plot design with 2 factors under study: i) pruning system, with 2 systems (mechanical pruning in hedge and manual pruning) and ii) dose of MSW compost, with 4 doses (0, 5000, 10000 and 20000 kg ha^{-1}). The experiment was installed in 2018. We present only the results of the 2020 vintage. The results obtained showed that the mechanical pruning significantly increased the number of bunches, without changing their weight, also increasing the yield per plant. Mechanical pruning also affected the composition of the grapes. The grapes from mechanically pruned grapevines had a higher probable alcohol content (PAC), slightly higher pH and less total acidity, when compared to grapes from manual pruning. Regarding the application of MSW compost, there were no significant differences in the parameters evaluated, except in the content of assimilable N in the grapes, which tended to be higher in the treatments with MSW compost, due to the availability of nitrogen from this organic fertilizer. The interaction between the factors under study was not significant, for all parameters evaluated. Mechanical pruning and fertilization with MSW compost may have a positive effect on vineyards, not only due to the increase in yield, but also due to the economic gain due to the reduction of labor with pruning and, also, for the environmental benefit thanks to the recycling of MSW.

Keywords:

mechanical pruning, urban solid waste (MSW), vegetative-reproductive balance, production yield, grape quality.

Resumo

Este trabalho teve como objetivo compreender como a interacção entre a poda mecânica (MEC) e a fertilização orgânica da vinha com composto de resíduos sólidos urbanos (RSU) pode trazer benefícios do ponto de vista do crescimento vegetativo, reprodutivo e da qualidade das uvas. O estudo foi realizado na Quinta do Gradil, Vilar, Cadaval, na região vitivinícola de Lisboa, numa vinha da casta Sauvignon Blanc, num delineamento strip-plot com 2 fatores em estudo: i) sistema de poda, com 2 sistemas (poda mecânica em sebe e poda manual) e ii) dose de RSU compostado, com 4 doses (0, 5000, 10000 e 20000 kg ha^{-1}). O ensaio foi instalado em 2018, apresentando-se apenas os resultados relativos à campanha de 2020. Os resultados obtidos mostraram que a poda mecânica aumentou significativamente, o número de cachos, sem alterar seu peso, aumentando, também, o rendimento por planta. A poda mecânica afetou também a composição das uvas. As uvas provenientes de videiras podadas mecanicamente apresentaram maior teor de álcool provável, pH ligeiramente superior e menor acidez total, quando comparadas com as uvas da poda manual. Relativamente à aplicação de RSU compostado, não se observaram diferenças significativas nos parâmetros avaliados, exceto no teor de N assimilável nas uvas, que foi tendencialmente superior nas modalidades com RSU compostado, consequência da disponibilização de azoto por parte deste fertilizante orgânico. A interação entre os fatores em estudo foi sempre não significativa, para todos os parâmetros avaliados. Conclui-se, assim, que a poda mecânica e a fertilização com RSU compostado poderão ter um efeito positivo na viticultura, não só pelo aumento do rendimento, mas também pelo ganho económico devido à redução da mão-de-obra com a poda e, também, pelo benefício ambiental graças à reciclagem dos RSU.

Palavras-chave:

Poda mecânica, resíduos sólidos urbanos (RSU) compostados, balanço vegetativo-reprodutivo, produção, qualidade das uvas.

Resumo desenvolvido

Este trabalho acrescenta-se a todos os estudos que tentam compreender como a interacção entre a poda mecânica (MEC) e a fertilização orgânica da vinha com composto sólido municipal (RSU) pode trazer benefícios do ponto de vista do crescimento vegetativo e do rendimento e qualidade das uvas. Em estudos anteriores, notou-se que as vinhas podadas com MEC tinham tendência a produzir mais do que vinhas podadas manualmente (MAN). Esta tendência deve-se ao facto de com MEC restarem mais olhos, obviamente dentro de um limite tal que a planta reage com um rendimento mais elevado, pelo que isto não se deve ao número de olhos deixados à poda mas a um mecanismo de auto-regulação da planta. A auto-regulação é um mecanismo fisiológico que permite à planta gerir a disponibilidade de nutrientes durante as diferentes fases fenológicas.

De acordo com alguns estudos, entre as variáveis controláveis presentes na vinha, a mais influente na auto-regulação é a densidade de plantação, seguida por todas as outras opções agronómicas, incluindo o método de poda e de fertilização. Portanto, este estudo também pode ser visto como uma análise de como a poda mecânica e a fertilização orgânica interagem com o rendimento da planta e a qualidade das uvas produzidas. Centrando-se na composição químico-física das uvas, verificou-se que esta não foimuito influenciada pelo método de poda, mesmo que em alguns casos a poda MEC tenha trazido resultados interessantes. Do ponto de vista físico-mecânico verificou-se um aumento da resistência à abcisão do pedicelo, um aumento da elasticidade e resistência da película à ruptura, enquanto que do ponto de vista puramente químico os resultados não foram significativos.Outro factor determinante de grande influência no rendimento e qualidade dos frutos é o equilíbrio vegetativo-produtivo, um parâmetro que está intimamente relacionado com a auto-regulação da planta. Uma planta que cumpre estes requisitos é aquela que inicialmente tem sarmentos que crescem e se alongam rapidamente e, depois, no período de frutificação, abrandam o seu crescimento e pouco antes do pintor param de crescer. Desta forma, formar-se-á uma superfície foliar adequada para suportar a maturação das uvas e para fornecer as substâncias de reserva para o ano seguinte. Se isto não acontecer e depois do pintor os sarmentoscontinuarem a crescer, os fotoassimilados, polifenóis e antocianinas não se acumulam no bago, em resultao da competição com o crescimento vegetativo.

Em relação à fertilização orgânica, notou-se que a utilização de RSU melhora o rendimento sem perda significativa da qualidade, provando ser uma boa opção para aumentar a rentabilidade das vinhas. Deve ter-se em conta que devemos prestar atenção à natureza destes compostos, porque se contiverem metais pesados, devemos evitar a sua acumulação, poluindo as terras agrícolas, porque para além da acumulação potencial no solo, tornando-o menos fértil, devido à sua toxicidade, podem causar poluição das águas subterrâneas. Devido à emergência de Covid,

os parâmetros que determinam o crescimento vegetativo, tais como a área foliar, a estrutura da sebe e as trocas gasosasnas folhas, não foram recolhidos. O estudo foi realizado na região vinícola da Quinta do Gradil perto de Lisboa, a vinha estudada é plantada com Sauvignon Blanc e foi dividida em 4 blocos repetidos aleatoriamente. Em cada bloco foram comparados os resultados obtidos com os diferentes métodos de poda: MEC vs. MAN; a fertilização foi avaliada comparando 4 tratamentos diferentes: o controlo (Ctrl) não foi fertilizado, os outros 3 foram tratados com doses diferentes: 5000 kg ha^{-1}, 10000 kg ha^{-1} e 20000 kg ha^{-1} do mesmo composto orgânico RSU.
Para maior clareza, este foi o terceiro ano em que as parcelas foram fertilizadas por este método. Até agora, a interacção entre os dois factores não mostrou qualquer efeito estatisticamente significativo, tanto no rendimento da planta como nos parâmetros caracterizadores da qualidade da uva, tais como: teor provável de álcool (CAP), pH, acidez total e azoto assimilável.
Considerando o azotocomo o principal elemento que influencia o crescimento vegetativo e aprodução da planta, estes resultados podem ser explicados pela quantidade insuficiente de fertilizante orgânico administrado, incapaz de libertar azoto suficiente para permitir um aumento da produção. É desejável continuar o estudo quer administrando as mesmas doses durante vários anos e ver se, com o tempo a matéria orgânica estável no solo aumenta para que o azoto libertado seja mais eficaz e duradouro, quer avaliar a possibilidade de aumentar a dosagem e/ou a concentração para a tornar disponível no mais curto espaço de tempo possível, considerando também o valor do produto. Não devemos esquecer a avaliação do nível de metais pesados no solo e decidir se devemos alterar o tipo de RSU a fim de evitar a acumulação destes elementos que são prejudiciais ao solo e à saúde humana. Uma normalização e uma certificação de qualidade da composição dos RSU tornariam estes produtos mais utilizáveis para os viticultores mais cépticos, aumentando a sua difusão e tornando ao mesmo tempo possível a redução destes resíduos no ambiente, tornando possível um círculo virtuoso eco-sustentável. Esta escolha pode também ser uma estratégia de marketing que oferece um produto no mercado destinado a consumidores sensíveis à protecção ambiental. A sustentabilidade e validade da tese é apoiada pelo trabalho de outros autores que demonstram como a interacção do MEC e dos RSU conduz não só a um bom rendimento do produto agrícola mas também a um ganho económico tangível devido à redução do tempo de trabalho, com o MEC, e especialmente a um benefício ambiental graças à reciclagem dos RSU.

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- assimilable nitrogen: **Ass N**
- cationic exchange capacity: **CEC**
- climate classification by Köppen-Gaiger: **Csb** (**Cs**: temperate climates with dry summer; **b**: with average temperature of the hottest month below 22 °C; at least 4 months above 10°C.)**.**
- European Master in Viticulture and Enology: **EMaVE**
- manual pruning: **MAN**
- mechanical pruning: **MEC**
- municipal solid waste: **MSW**
- organic amendment: **OA**
- pre-mechanical pruning and subsequent manual finishing: **Mm**
- pre-mechanical pruning and simultaneous fast finishing using a trailer with two operators equipped with pneumatic scissor: **Mw**
- polychlorinated biphenyl: **PCB**
- probable alcohol content: **PAC**
- Quinta do Gradil: **QG**
- Ravaz index: **RI**

1. Introduction

The project of this thesis was born during my EMaVE (European Master in Viticulture and Enology) experience at the University of Lisbon. The curriculum included a practical field internship at Quinta do Gradil where the aim was to study the combined effect of mechanical pruning and organic fertilization.

Due to the health emergency I could not provide the complete data collection but it was possible to reconstruct an analysis thanks to the data collected by MSc. Manuel Botelho.

In viticulture, a careful study of the soil, the climate, the choice of the vine variety and its care, using the correct fertilization, and pruning are important for controlling the production and quality of the oenological product.

The interaction between fertility and winter pruning affect the nutritional and physiological state of the plant and finally the yield and composition of the grapes.

Over time, various types of fertilization associated with different kinds of soil, climate and vine types have been studied. Particularly:

- a fertilization that takes into account compost of urban solid wastes (MSW) considering their composition: mineral, organic and the presence of heavy metals.

Considering that the various types of pruning have always been linked to the seasonal period it will be examined:

- the application of mechanical winter pruning followed by a light manual follow up where permitted by the type of training system and the orography of the soil.

These two moments of wine-growing care should lead, if well combined and applied in the right context, to a net improvement in the quantity of the wine product and a high quality of the final oenological product.

2. Aims of Work

For over forty years, the effects of fully mechanized pruning systems on the physiology, vigor, yield and quality of the grapes have been studied. In particular, because they represent an interesting alternative to reduce production costs. On the other hand, organic fertilization represents an effective way to increase vine productivity.

The aim of this work was to evaluate the interaction between mechanical pruning and the increase of soil fertility through the use of MSW compost, and how these influence the vegetative growth of the vine, the yield and also the quality of the grapes, with a look at the eco-sustainability of MSW treatments and the safety for food use.

3. State of Art

3.1 Terroir and soil fertility

The terroir consists of the grape variety, the climate, the soil and the viticultural and oenological techniques. These factors interact to provide an original wine in terms of quality and typicity.
Soil and subsoil are two fundamental pillars in the production of quality wines whose chemical and sensory characteristics are influenced by their geological origin, its interaction with the plant, and the care that man puts into the soil (Fregoni, 2013a).
The soil is a dynamic system in fact it is formed after a series of pedogenetic processes that are carried out by the parent rock, whose characteristics are constantly changing, both in the short term (e.g. temperature and water content), and in the long term (e.g. soil reaction, presence of soluble salts, amount of organic matter, number of microorganisms, soil fauna, etc.) (Masoni, 2015; Palliotti et al., 2018a).
In essence, soil is an important factor that allows the development of the vine and affects the quality of the grapes. (Masoni, 2015; Palliotti et al., 2018a).
In Europe, the vineyard is one of the agricultural ecosystems with the lowest soil carbon content (Longbottom and Petrie, 2015) and the one with the highest risk of erosion (Kosmas et al., 1997). The decrease of carbon in vineyards intensifies in the Mediterranean regions, due to the climate, especially during late spring and summer, this is due to high temperatures associated with long periods of drought (Fraga et al., 2012). This effect is further enhanced by Global Warming. Mediterranean viticulture is facing serious risks and adaptation measures are needed to address this problem. Among these measures, organic fertilization of soil is highlighted (Fraga et al., 2012).
The fertility of a soil is the aptitude of a soil to produce. To take into account, however, is that fertility is not something that refers only to the soil, but to the soil-plant system.
A soils excessively rich in elements and endowed with particular physical fertility without limiting factors such as water, can induce the plant to increase vegetative growth at expense of the production and ripening of the fruit; in some cases it is required that the plant enters into stress to stimulate the synthesis of tannins and anthocyanins (Palliotti et al., 2018b).
Various types of fertility are distinguished:
- Chemical fertility - the presence of available macro and micro-elements.
- Physical fertility - texture (percentages of silt, clay and sand), structure (organization of particles with organic and inorganic cements, formation of colloids, porosity divided into microporosity for water and macroporosity for air), etc..
- Biological fertility - macro, meso and microfauna (primarily bacterial biomass).

3.2 Fertilization

The fertilization of vineyards has a particular interest because it has a significant impact on the qualitative and quantitative aspects of production (Storchi and Perria, 2016). The possible influence of cultivation techniques on quality has received a lot of interest from winegrowers and technicians as they represent variables that operators can change in the short term.

For a long time, it was thought that there was no need to fertilize the vineyards, as without it, it was possible to obtain good results, but it was seen that the vine has specific nutritional needs related to the amount of mineral elements removed per year and per hectare.

Today, therefore, it is possible to supply nutritive elements in order to eliminate or prevent the deficiencies manifested by the plant, such as a decrease in production. This is done in order to obtain better quality and yield through a dosed and balanced fertilization (Fregoni, 2013a; Storchi and Perria, 2016).

The mineral nutrition has a decisive influence on the wine production quality, so the application of mineral fertilizers is now an essential practice. Macro and micro-elements are in fact able to modify the content of carbohydrates, proteins, amino acids, organic acids, aromas and vitamins of must. Mineral fertilizers are specific fertilizers that only increase chemical fertility (they bring one or more chemical elements to the soil) (Cardelli, 2015).

Some examples can be provided by some studies that have shown that:

- Nitrogen and potassium can modify the phenolic composition of grapes on cv. Tempranillo (Delgado et al., 2004);
- Nitrogen nutrition can influence the colour density of the must by stimulating anthocyanin synthesis in the grape skins during ripening. There is a strong N:K interaction, optimal N:K nutritional ratios can improve the phenolic characteristics of the grapes; in fact the degree of polymerization of condensed tannins decreased when the N:K ratio was balanced and the amounts of both nutrients applied were high (Delgado et al., 2004);
- It has been shown that high levels of potassium can have negative effects on the stability of wines as they cause an increase in their pH (Davies et al., 2006);
- Potassium tends to decrease the concentration of tartaric acid in the berry and must with the formation of potassium bitartrate which is not very soluble, while the concentration of malic acid increases (Terrier and Romieu, 2001).

3.2.1 Nitrogen

Nitrogen is the most important macroelement and, in fact, it constitutes 1-6% of the dry matter of the plants (Palliotti et al., 2018b). In soil, N concentration is equal to 1-2$^{0}/_{00}$ (mg/g or g/kg). Regarding N fertilization, this nutrient is easily leached after planting because it is very mobile in the soil.

It is present in the following forms:

- elemental (soil air, it is not available to the plant);
- in the soil solution it is mineral (1-5% of the total)
- and organic (95-99% of the total).

The only nitrogen available to the plants is mineral nitrogen (1-5% of the 1-$2^{0}/_{00}$ total), it is a very low amount and that is the reason why crops need N fertilization.

An agricultural soil is a nitrogen-poor soil; to solve this problem, it is necessary to fertilize annually (Cardelli, 2015).

How much nitrogen is available in one hectare of land?

For example: It starts from the weight of one hectare of soil, which is variable: if the crop (not necessary vine) is not known, considering 25 cm (clearly for vine this value is too low, since the vine's root are deeper) depth and apparent specific weight of about 1.2 ton/m^3; you get 3000 tons per hectare. The minimum value, of the average presence of total nitrogen $1^{0}/_{00}$ in 3000 t, is 3 t of nitrogen present in the soil: this is the total nitrogen, both organic and mineral (telluric air is neglected). The mineral nitrogen (ammonium nitrogen NH_4^+, nitrous nitrogen NO_2^-, nitric nitrogen NO_3^-) is 1% of 3000 kg, so it is 30 kg of nitrogen per hectare (Cardelli, 2015).

Organic forms are in the form of:

1. Undecomposed substances: proteins, nucleic acids and amino acids, 50% in the form of amine and amide.
2. Humified substance: 50% in heterocyclic form (pyrrole and pyrimidine).

Most elements in organic form must be mineralized in order to be taken up by plants. Organic nitrogen must be transformed into ammonium nitrogen and then into nitric nitrogen (figure 1), a process that is the responsibility of microorganisms (Amlinger et al., 2003; Taiz et al., 2016).

The N mineralized by organic fertilizer varies from 5-15% in the first year and 2-8% in subsequent years as a percentage of total N compost. The dynamics of N mineralisation is mainly determined by soil properties such as total C, total N, C/N ratio, soil structure and water retention capacity (Amlinger et al., 2003).

[ammonification; step 1]	(humus)-R-NH_2 + H_2O	→	NH_3 + R-OH
[ammonification; step 2]	↑NH_3 + H_2O	→	NH_4^+ + OH^-
	[*Nitrosomonas*]		
[nitrification; step 1]	$2NH_4^+ + 3O_2$	→	$NO_2^- + 2H_2O + 2H^+$
	[*Nitrobacter*]		
[nitrification; step 2]	$2NO_2^+ + O_2$	→	$2NO_3^-$
[denitrification; general sheme]	$2NO_3^- + 10e^- + 12\ H^+$	→	$N_2 + 6H_2O$

Figure 1 Main reactions in the soil of the N component (Amlinger, 2003)

3.2.2 Phosphorus

Regarding the P and P fertilization the second key macro-element for life is phosphorus, the vine's needs are not high, so planting fertilization can provide nutrition for several years.

Phosphorus is contained in organic compounds as ATP, ADP, nucleic acids, phospholipids, phosphoproteins (Cardelli, 2015).

Phosphorus is fundamental for the development of the root system (Cardelli, 2015).

In plants it constitutes 0.2-0.3% of dry matter. In soil the total phosphorus is 1-$2^{0}/_{00}$, i.e. 1-2 g per kg of soil (Palliotti et al., 2018b).

The phosphorus in the soil is half mineral and half comes from organic matter (Cardelli, 2015; Palliotti et al., 2018).

However, the percentages depend on the type of soil, so there are large fluctuations of these values (Cardelli, 2015). Phosphorus inputs to the soil come from organic matter, parent rock and fertilization. Losses are caused by crop removal, erosion and insolubilisation in the soil solution (Cardelli, 2015).

Although phosphorus is present in the soil, it is not very available, as it tends to precipitate and form new minerals: in acidic soils it becomes unavailable in the form of iron or aluminium phosphates and undergoes fixation, while in subalkaline soils calcium phosphates are formed which are not available for the plant (Cardelli, 2015).

Phosphates added with fertilisation are very stable in the soil but are not available for plant nutrition.

The forms absorbed by plants are in the form of $H_2PO_4^-$ and HPO_4^{2-} anions at pH 5-9 typical of the soil in which the presence of the two anions is guaranteed (Cardelli, 2015).

At pH 7 we have the greater availability of both anions: towards acidity we have $H_2PO_4^{2-}$ up to the extreme acidity where there is H_3PO_4; towards alkalinity we have HPO_4^{2-} up to the extreme alkalinity where there is PO_4^{3-}.

The phosphorus present in the soil comes from the alterations of minerals stimulated by mycorrhizae and radical exudates (phosphate release). A small amount is consumed by microbial biomass. The metabolism is maintained by recycling organic phosphorus. Microorganisms and higher plants release enzymes into the soil, which catalyze the release reactions of the phosphate contained in the organic matter (Cardelli, 2015).

Schreiner et al. (2013), from studies in the vineyard saw that P fertilization did not affect growth and yield, while Conradie and Saayman (1989), observed an increase in yield and growth with only 9 kg P ha^{-1} $year^{-1}$ in soil that was originally lacking this nutrient. Obviously these results also need to be contextualized in the area where one is working.

3.2.3 Potassium

The third fundamental macronutrient present in the soil useful to plants is potassium.
Total potassium in the soil is 0,5-2%, i.e. 10 times more compared to nitrogen and phosphorus (Cardelli, 2015).
Potassium is present exclusively as monovalent cation K^+ in the soil solution and is assimilated by the plant in this form.
Different forms of potassium can be distinguished in the soil: the one that constitutes the crystalline reticles, the one that is imprisoned in the crystalline reticles, finally the exchangeable K and the K in solution. The sum of the latter two is the potassium available for the plant, 1-2% of the total K in the soil (Cardelli, 2015; Palliotti et al., 2018b).
The wine vine requires up to 3 kg of potassium per tonne of grapes harvested (Edagricole, 2006).
Potassium is important in plants because:

- it regulates the permeability of cell membranes, catalyzes the synthesis of sugars and fats; it is a promoter of photosynthesis and is involved in the active translocation of sugars from leaf to fruit (Agronotizie, 2006).
- It plays an important role in determining the size of the berries and consequently influences the final yield of the crop. However, the results of its application are inconsistent some authors found slight increases in yield (Conradie and Saayman, 1989), while others found no differences (Delgado et al., 2004) or small reductions (Kliewer, 1983).
- It regulates the opening and closing of the stomata thus improving the efficiency of water use by the vineyard (Agronotizie, 2006).
- it regulates the acid-base balance; it guarantees the growth of the mechanical tissues of the plant, such as root tips and shoots; increases cell turgor;
- improves the texture and flavour, aroma and flavour of the fruits, which are more intense in colour and richer in sugar (Storchi and Perria, 2016; Cardelli, 2015).

To perform its best functions, potassium must always be administered to the vineyard in balanced ratios with respect to other cations, in particular calcium and magnesium, so as to avoid obvious deficiencies in the plant and to avoid competition at root level between these elements. (Agronotizie, 2006; Palliotti et al., 2018b).

3.2.4 Magnesium

Regarding magnesium, it is present in plants for 0.03-0.64% of dry matter. It is a fundamental constituent of chlorophyll: in fact, at the centre of the pyrrole nucleus there is a magnesium atom that gives the green pigment to plants. It activates many enzymes and is present in young tissues and fruit.

In the soil the total magnesium ranges from 0.05-5%. An in-depth analysis of the soil revealed a deficiency of this element to be evaluated and corrected with appropriate fertilisation.
In acidic soils, a calcium-magnesium correction can be used, while in neutral or calcareous soils magnesium sulphate is suitable (Fregoni, 2013a).

3.2.5 Planting fertilization and production fertilization

The planting fertilization is the one carried out just before the planting in order to correct the chemical deficiencies of the soil and to allow the young vineyard to develop in a soil sufficiently rich in nutrients, therefore essential macroelements, such as P and K, must be applied.
Acidity is the main cause of unfavorable soil conditions. At a strongly acidic pH the microelements are absorbed in large quantities and may cause toxicity (Palliotti et al., 2018b). In these cases, a corrective fertilization will be carried out with an adequate liming, followed by ploughing at about 50 cm and ripping (Fregoni, 2013a).
Production fertilization involves the addition of fertilizers to provide nutrients for crop needs and to maintain soil fertility. When dosing the fertilizer it is necessary to take into account both the crop needs and the impoverishment of the soil due to phenomena such as leaching, denitrification and mineralization.

3.2.6 Organic fertilizers

Humus is a key component in soil, since affects its physical, chemical and biological properties.
Humus has a great agronomic importance in soil structure, contributing to a granular structure of the soil, which determines the physical stability and avoids soil compaction, thus favoring all the chemical-biological phenomena that occur in the soil. The granular structure is linked to the clay-humic complex, i.e. the product resulting from the union of two electronegative colloids (clay and humus) by bridging some positive cations, in particular calcium, which is a fundamental element in soil fertility.
Humus plays, also, an important role in the mineral absorption by the roots.
Humus in soil prevents the degradation of the granular structure and compaction, the biological sterilization of the soil, and the progressive liming of soil (Fregoni, 2013a; Palliotti et al., 2018b).
From the microbiological point of view should be highlighted the microbial activity in soil, such as the production of antibiotics, hormones that regulate root growth, necessary for the absorption of minerals and water, the chelating action towards iron, the solubilization of phosphates, etc. (Storchi and Perria, 2016; Palliotti et al., 2018b).
Humus is therefore indispensable to soil life and to soil fertility, chemistry and microbiology.
The source of humus is organic matter, which is transformed into humus by soil microorganisms (humification). The composition of the humus is complex and includes:
- imatomelanic acids (affect the soil structure),

- humic acids (which promote the absorption of mineral elements through chelation, i.e. forming humates),
- fulvic acids (which solubilize the minerals making them free),
- organic acids,
- phenolic acids, polyphenols,
- proteins, lipid amino acids (which perform chelating functions),
- hormones,
- vitamins,
- enzymes (urease, dehydrogenase, phosphatase, cellulase, phenol oxidase, etc.).

In vineyards the organic matter is often less than 1%, especially in southern and warm areas, when the optimum should be about double (Fregoni, 2013a).
The organic matter can give rise to stable humus, which is more resistant to oxidation and high temperature, or labile humus, which is decomposed more quickly (Masoni, 2015).
Straw, shoots, wood (because they are rich in lignin) produce stable humus, while labile humus is produced by manure, green manure and grass and leguminous (Fregoni, 2013a; Masoni, 2015).
Soil organic matter, through the mineralization process carried out by soil microorganisms, originates available nutrients, namely nitrogen, a sensitive element in the vineyard, as both deficiency and excess can be harmful to the quality of the wine (Masoni, 2015; Palliotti, Poni e Silvestroni, 2018b).
The winemaker who wishes to obtain wines of terroir must follow many rules in order to produce quality grapes, i.e. perfectly ripe and rich in micro-compounds that are the basis of the excellent quality.
In wine there is a macrostructure (alcohol, acids, etc.) and a microstructure (aromas, enzymes, etc.) and it is the latter that represents the organoleptic and sensory personality of the wine. The composition of wine is so complex that it is difficult to establish which factors of terroir are related, but it is certain that the biological life of the soil and the chemical-physical composition of the soil are among the indispensable conditions for the production of terroir wines (Fregoni, 2013a).
The preservation of soil fertility is one of the essential aims of the winegrower's activity, Consequently, maintaining an adequate level of organic matter and stable humus is part of the objectives of sustainable viticulture.
A structurally, chemically and biologically fertile soil reinforces the vine's endogenous defenses by the synthesis of resistance molecules such as resveratrol, tannins, quercitin, etc. (Fregoni, 2013a).
Together with mineral fertilizers, organic fertilizers are needed to stimulate soil microbial life, the continuous long-term application of organic fertilizers has a positive effect on soil quality as it increases microbial activity and physical and chemical properties (Cardelli, 2015; Calleja-Cervantes et al., 2015; Santos, 2012).

Organic fertilizers have shown a greater influence on the denitrification potential and N_2O/N_2 ratio than mineral fertilizers (Calleja-Cervantes et al., 2015), this can be explained by the fact that with a higher organic component it leads to higher fertility and consequently a higher vitality of the microorganisms that through their enzymes carry out the denitrification processes (Cardelli, 2015). Inorganic nitrogen is also partially immobilized by the microbial biomass that uses it for its own cycles. The balance between mineralization/immobilization depends on the carbon/nitrogen ratio (optimal ratio is about 10-20 corresponding to good mineralization and low immobilization) (Cardelli, 2015).

One thing absolutely not to be underestimated, besides deep tillage, is the overuse of the soil. Without an adequate supply of organic matter by organic fertilizer to the soil, of which it has been deprived during the year, there will be a decrease in fertility. It must be remembered that the process of humification of organic matter is a chemical-physical process that needs many years to form again based on the starting compounds. (Masoni, 2015; Fregoni, 2013a; Cardelli, 2015; Palliotti et al., 2018b).

However, organic fertilizer cost and the difficulty of finding and distributing them represent some serious limitations to their use (Zhang et al., 2013).

The main organic fertilizers are:

- Peat - it is a typical formation of partially decomposed organic material in marshy (or reclaimed) or submerged environments, with low density, mainly used in nurseries. They can be of two types:
    - Calcic, with subalkaline pH, between 7-8, very high TSB (where there is calcium the TSB is always high) and C/N ratio less than 30.
    - Acidic, with acidic pH, between 4-5, low TSB and high C/N ratio.
- Manure - provides organic matter and nutrients. When not mature (fresh animal manure), may have a high concentration of harmful compounds (for example, urea if concentrated may be harmful to seeds).
- Composts from different wastes have gained interest in recent times and are used in agriculture because they improve the physical properties of the soil and provide essential nutrients to plants (Amlinguer et al, 2003). However, due to the composition of the wastes used, composts, like MSW compost, may have heavy metals. Consequently, the use of compost may increase metal loads to soil, as a direct consequence of the metal content of the organic materials used. However, most metals applied with compost are retained in the modified soil and the presence of organically bound forms tends to increase over time. The amount of dissolved organic matter derived from compost may be responsible for the mobilisation of organo-metal soluble complexes from modified soils, and subsequent adsorption to mineral surfaces in deeper horizons. However, the loss of organically bound forms of particular metals from the underlying mineral horizons suggests that this same path

could potentially lead to some leaching of metals from the soil system (Businelli et al., 2009). Green compost, produced only through pruning of public and private gardens, is currently safer and more organic than MSW (Hargreaves et al., 2008).

- In recent years, under the ecological drive of biological waste disposal, some recycled materials have become part of the organic matrices. For example, the tanning industry produces by-products that are useful for soil fertility.
- Other natural organic products like dried blood (it is rich in nitrogen and phosphorus, collected from slaughter), meat and bone meal (rich in phosphorus and sulphur), wool waste (rich in nitrogen, obtained from sheep shearing), leather waste (Cardelli, 2015).
- Biochar which is a co-product of a thermochemical conversion of biomass (originated from vegetal coal) that is recognized as a beneficial amendment of the soil that, once incorporated into the soil, increases the retention and availability of water (Baronti et al., 2014) and nutrients (Lehmann et al., 2006).

3.2.6.1 Use of compost and its effects on soil

In a long-term fertilisation trial with different crops, Bartl et al. (2002) studied three fertilization systems: non-fertilized control (O), mineral fertilizers with 83:52:95 kg ha^{-1} (NPK) and biocompost with 32 Mg ha^{-1} of fresh matter (BC). Authors found that fertilization strongly influenced electrical conductivity, cation exchange capacity, content of organic C (Corg) and water-soluble Cl and SO_4 (Tabel 1). Conductivity increased from non-fertilized control (O) to mineral fertilizer (NPK) and compost (BC) treatments, with significant differences between “O” and “BC”. Cationic exchange capacity, water-soluble C org and water-soluble Cl content were significantly higher in BC treatment than in other treatments.

On the contrary, BC or mineral fertilisers did not lead to significant differences in pH, carbonate content and water-soluble PO_4 in the soil, compared to non-fertilized control (Table 1)

Table 1: Some soil parameters and water soluble anions from three fertilization systems: non-fertilized control (O) mineral fertilizers (NPK) and biocompost (BC). Values with different letters differ significantly (P<= 0.05) (Bartl et al., 2002)

	unit	O	NPK	BC
pH (KCl)[a]		7.48	7.47	7.53
$CaCO_3$	g kg^{-1}	281	273	280
EC[b]	mS cm^{-1}	0.37 a	0.39 a	0.43 b
CEC[c]	$Cmol_{(+)}$ kg^{-1}	11.2 a	11.2 a	12.0 b
C_{org}	g kg^{-1}	18.8 a	19.4 a	23.2 b
Cl	mg kg^{-1}	6.10 a	6.43 a	10.15 b
SO_4	mg kg^{-1}	11.7 a	22.0 b	13.4 a
PO_4	mg kg^{-1}	1.95	2.75	2.87

Organic fertilizers contain nitrogen, and the N release depends on the fertilizer properties. In compost, the duration of N release is about four years after application, but most of N was already available in the first two years, suggesting that it is better to apply compost every two years rather than every four (Zhang et al., 2013). Raw material selection, aeration and maturation are some of the parameters that have been identified as responsible for the N content of composts (King, 1984; Korner, Stegmann, 2000; Abu-Qdais, Hamoda, 2004).

The results showed that the release of N and S from compost was high in the first year of application and then decreased every year, while the release of P from compost was constant during the four years of testing.

The inorganic N content in the compost may have low values, in order to meet crop requirements often additional compost is applied, but this practice often leads to excess of other nutrients. The addition of inorganic nitrogen fertilizer to the compost could solve this problem, but the compost would not satisfy bio-organic standards.

The physical and chemical composition of composts tends to change according to time and source, so annual monitoring of compost quality is necessary (Hicklenton et al. 2001) through analytical procedures and using a standardized quality index for the measurement of organic pollutants, such as polychlorinated biphenyl (PCB) that may contaminate the product.

The annual variation of the properties of compost, coming also from the same source, prevents researchers from drawing definitive conclusions and inhibits the research and the effective use of the compost itself (Mamo, 1999).

Researchers and people using compost need to be sure that they are constantly receiving a quality product. The implementation of these recommendations could reduce opposition to the agricultural use of compost and encourage the use of the product (Hargreaves et al., 2008).

The duration of the release from compost of N is approximately 4 years after application, but most of N was available in the first two years, suggesting that the application of compost every two years is better than once every 4 years (Zhang et al., 2013).

Summarizing the use of MSW compost the following should be taken into account:

- the optimal application rate for crop production;
- and the number of applications a soil can receive so as not to violate government regulations.

Future research should also focus on the state of metals in the soil (i.e. form, solubility and mobility) and their bioavailability to plants (Zhang et al., 2013).

Therefore, the recycling of waste, besides being environmentally and economically motivated, bio-waste compost is suitable to provide the soil mineral nutrients removed from the crop (Bartl et al., 2002).

3.2.6.2 Effects of compost on the vineyard and content of heavy metals

Pinamonti (1998) found that the use of compost from MSW increased concentrations of Zn, Ni, Pb, Cd, and Cr in soils, and, also, an increase in Zn in vine leaves and must. However, no symptoms of phytotoxicity by metals were observed in the study.

In the case of nutrients and heavy metals, the values of all plots (Table 2) were within the natural range for most samples, therefore it is considered that these composts can be used for agricultural purposes given their non-toxicity (Bartl et al., 2002; Pinamonti, 1998).

Table 2: Total element contents (aqua regia) of different plots and classification according to the five step scheme of the lower Austria soil inventory (Anonymous, 1994). Average values from 6 replicates, values with different letters differ significantly (P<= 0.05) (Bartl et al., 2002).

	Treatment			
Element (mg kg^{-1})	**Control**	**N**	**BC**	**classification**
K	2660	2749	2602	-
Mg	31300	30800	31000	-
P	807	800	860	-
Cu	29.9	29.2	31.7	natural content, high 25-50 mg kg^{-1}
Mn	651	644	662	natural content, medium 500-700 mg kg^{-1}
Mo	0.62	0.71	0.64	natural content, high 0.6-2.0 mg kg^{-1}
Zn	69.7 a	67.9 a	76.1 b	natural content, medium 60-90 mg kg^{-1}
Cd	0.56	0.50	0.51	increased content 0.5-1.0 mg kg^{-1}
Ni	32.6	32.0	32.5	natural content, high 30-40 mg kg^{-1}
Pb	23.9 a	24.6 a	26.4 b	natural content, high 20-30 mg kg^{-1}

However, it is necessary to be careful with the use of organic fertilizers because it can cause an increase in the level of Cr (a particularly dangerous element for human health), in soil, leaves and must (Korcak, 1989; Cienslinki et al., 1995; Cieslinki et al., 1996).

The compost obtained from poplar bark sludge (SB) contains less heavy metals than MSW compost, and caused only significant increases of Zn in the soil, while it did not produce changes in the concentrations of the other heavy metals tested. This compost can therefore be considered a suitable alternative to fertilizers for sustainable viticulture (Pinamonti, 1998). Another sustainable compost is biocompost, which, although it has been used for several years, has not led to accumulation of heavy metals, respecting the limits of the regulations in vigor. Therefore biocompost in the context of waste recycling, environmentally and economically motivated, is suitable to provide the soil with mineral nutrients that have been removed from the plant (Bartl et al., 2002).

Considering again the MSW compost, one thing to do in the coming years is to try to make safe and sure the use of these fertilizers that, besides being a source of improvement of soil fertility, can reduce the impact of waste on the environment, since a lot of waste material would be reused to produce primary human goods (Bartl et al., 2002).

It is therefore important to know the possible heavy metal contamination from MSW compost, so that it can be minimized through organizational and technical measures during collection, treatment and composting (Kehres et al., 1997; Traulsen et al., 1997; Plahl et al., 2000).

Sewage sludge should not be added to compost, as it would increase the content of Ni, Pb, Se, Zn and Cu (Richard and Woodbury, 1992; He, 1995). Copper or zinc levels can serve as indicators of sludge addition to MSW compost, their concentration should remain below the limits of the guidelines (Vassilev, Braekman-Danheux, 1999).

For use on agricultural land it is necessary to know the bioavailability of metals and the factors that influence their absorption by plants and their permanence in the soil: pH, cation exchange capacity (CEC), organic matter content and soil structure (Pinamonti et al., 1999). Research in this area should also consider that MSW compost may have effects such as increased pH and organic matter content in soil (Deportes et al., 1995; Mkhabela, Warman, 2005). A fraction of the added organic matter is resistant to decomposition, but some of the humic substances finally decompose releasing metals bound to this fraction. It is believed that inorganic residues such as phosphates, silicates, Fe, Al and magnesium oxide probably provide long-term metal retention, demonstrating the necessity of further experiments (McBride, 1995).

To avoid accumulating the same type of heavy metals in the soil with MSW compost, it may be necessary change the type of MSW every four years (Zhang et al., 2013).

3.2.6.3 Effects of compost on grape yield and quality

Several studies have been conducted on how MSW compost and manure could affect grape yield and quality. In a 4-year study, Botelho et al., (2020a) administered annually 16400 kg/ha of MSW in fresh weight and 24800 kg/ha of fresh manure, both equivalent to 5000 kg of dry organic matter. During the first year there were no changes, but in the following years manure fertilized soils gave rise to a significant increase in production yield, while those treated with MSW compost reported particularly positive results from the third year of the study. Similar results were also obtained by Conradie (2001), Messiga et al (2016), Gaiotti et al. (2017) and Ramos (2017).

It is known that manure has an N content higher than that of MSW compost. Nitrogen fertilization tends to increase the yield (Schreiner et al., 2013) up to 40-56 kg N ha^{-1} (Conradie and Saayman, 1989; Spayd et al., 1993), so one would expect a higher yield using manure, also because its level is lower than what Spayd et al. (1993) indicated as the maximum yield limit value. The response to fertilization with N is not always the same, as reported by Wolf and Pool (1988) who observed a trend decrease in yield as the application rate of N increased from 39 to 84 kg N ha^{-1}. In other studies, conducted by Pinamonti (1998) with MSW compost and Morlat (2008) with long-term (28 years) application of cattle manure, no differences in productivity were observed.

Recent studies have shown a higher yield using MSW compost and manure, without showing significant differences between the two, only in the second year of the four studies manure produced more. This result is probably related to a higher stability of N in MSW compost compared to manure and, consequently, this leads to lower leaching losses, lower impact on the environment and higher availability for vines (Botelho et al., 2020a).
According to Ramos (2017), who worked on young vineyards, the differences in yield, with the application of organic compost to the soil, are more pronounced in dry years, due to the important role of organic matter on the ability to retain water.
We can therefore conclude that the use of MSW compost and manure improve the yield without significant quality losses proving to be good options to increase the profitability of the vineyard.
As cattle manure is becoming less and less available, MSW compost seems to be a good option to increase soil organic matter and fertilize vineyards. However, these organic soil improvers usually have variable levels of heavy metals that need to be taken into account when deciding to use this option (as already mentioned before).

3.2.6.4 Effects of compost on vegetative growth

The growth of the vine seems to be less influenced by organic fertilization than the yield components. Botelho et al. (2020a) found that the number of shoots per vine was not affected by organic fertilization, neither in the control nor in the other two organic fertilization treatments (MSW compost and manure). However, the pruning weight per vine was increased with manure, in year 2 and 3, compared to the control, while MSW compost had an intermediate behavior (Botelho et al. (2020a). Pinamonti (1998), Conradie (2001) and Gaiotti et al. (2017) found similar results.
With organic fertilizers the Ravaz index (RI) was increased and dry matter production was increased, showing an increase in vine capacity. This can also be seen from the increased production of carbohydrates directed to the reproductive growth, compared to vegetative growth (Botelho et al 2020a). Therefore we must pay attention that the yield does not exceed a certain level, with a consequent excessive delay in ripening and a decrease in quality.
Gaiotti et al. (2017), in a vineyard pruned to cane and fertilized with manure, found no variation of RI. In the study conducted by Botelho et al. (2020) there was one variable: the choice of mechanical pruning. In this way the vines seem to have preferred to favour reproductive growth and reserve formation instead of bud development (Clingeleff and Krake, 1992), thus leading to an increase in RI.

3.3 Pruning

Depending on the soil, climate and the type of vine present, pruning is one of the agronomic techniques performed to obtain the best quali-quantitative result of the product.

The purposes of pruning are: to give shape and structure to the plant in order to maintain it over time; to maintain the vegetative-productive balance; to make the annual production constant (Storchi and Perria, 2016; Palliotti, et al., 2018c).
Pruning can be: manual, mechanical or mixed; considering the period of execution it can be winter or green.

3.3.1 Winter pruning

Before the phenomenon of the abscission, which causes the detachment of the foliar petiole from the shoot, many organic and mineral substances contained in the leaves are migrated into the shoot and from this into other organs of the plant: stem, branches, roots (Palliotti, et al., 2018c).It follows that, if possible, the vines should not be pruned before the leaves fall off (Fregoni, 2013b). From the harvest to the complete fall of the leaves many days often pass, even for late grapes, and the physiological state of the vine evolves towards a progressive decay of the synthesis activity, until it is annulled in the last acts before the foliar detachment (Fregoni, 2013b; Palliotti, et al., 2018c).
When the leaves on the plant are almost completely yellow or red or even worse necrotic is useless to wait for the fall of the leaves to prune; on the other hand it is always better to avoid an early pruning before the leaves fall, because this causes an early sprouting, leading the plant to go towards winter frosts or late spring frost.
The best time for winter pruning is from leaf fall until before bleeding.

3.3.2 Adaptation to *terroir*

Pruning technique is not unique, but it must be adapted to the terroir: soil, climate, vine and agronomic interventions and to the desired wine to be obtained, because some of the constituents, like the climate can vary from year to year (Fregoni, 2013b).
Keller et al., (2004) have observed that the effect of the seasonal climate is more influential than the pruning treatment in cordon trained at 1.8m.
In adverse climatic conditions of drought, it was noted that simulated mechanical pruning over a period of 11 years increased the yield, sugar production per vine plant and the production of dry matter (Toda and Sancha, 1999). Botelho et al., (2020b) noted that production yields in non-irrigated without losing quality have increased. These results indicate that mechanically pruned vines show an adaptation to stressful conditions (Botelho et al., 2020b). Different results were obtained by keller et al., (2004), where no yield improvement was seen in drought environments (Keller et al., 2004).
The reduction in yield by strict manual pruning or by mechanical pruning followed by hand finishing only marginally improved the quality of the fruit (Keller et al., 2004). Thus, mechanical pruning

have consistently produced heavy harvests of satisfactory fruit quality and good lignification of the shoots even in the cold seasons (Keller et al., 2004).

3.3.3 Vegetative-reproductive balance

One of the parameters that has a great influence on the yield and quality of the fruit is the vegetative-productive balance: it hides the possibility of achieving quality at any level of production as long as the leaf surface is efficient and sufficient (Storchi and Perria, 2016). A plant that meets these requirements is the one that initially has shoots that grow and lengthen rapidly, then in the fruit set period they slow down their growth and just before veraison they stop; in this way a suitable leaf surface will have formed to support the ripening of the grapes and provide the reserve substances for the following year. If this does not happen and after veraison the lateral shoots and other shoots continue to grow, the photoassimilates, polyphenols and anthocyanins will be reduced in the berry due to a competition with the young shoots (Palliotti, et al., 2018c).

3.3.4 Self-regulation

In order to reach the productive vegetative balance it is necessary to take into account the self-regulation. Self-regulation is a physiological mechanism which allows the plant to avoid wasting its available nutrients during the different phenological phases and regulating the vegetative-reproductive balance.
According to some studies, among the controllable variables present in the vineyard, the agronomic choice that most influences self-regulation is the plantation density, followed by rootstock, pruning method, fertilization, etc... (Spevis et al., 2020).
The work that will be discussed considers fertilization and pruning as controllable variables, it will be considered only the interaction between these two variables and how they affect self-regulation.

3.3.5 Comparison Manual and mechanical pruning

3.3.5.1 working time, costs and labor

Process of mechanization, which also includes harvesting and pruning, has led to a decrease of handlabor (Clingeleffer and Krake, 2002; Intrieri, and Poni, s. 1995; Martinez De Toda, Sancha, 1999; Possingham, 1996; Reynolds, 1988; Shultz and Weyand, 2005; Smart, Robinson, 1991).
All this was caused by the reduced availability of specialized workers in viticulture and induced by a constant increase in labour costs.
Several studies (Caprara and Pezzi,2013; Castaldi e Pezzi, 2014) were performed using the following winter pruning techniques on foothill areas.

- manual pruning (MAN);

- mechanical pruning (MEC);
- pre-mechanical pruning and subsequent manual finishing (Mm);
- pre-mechanical pruning and simultaneous fast manual finishing, using a trailer with two operators equipped with pneumatic scissors (Mw).

The adoption of mechanized pruning systems leads to reductions in manual work from 54 to 70% (Gatti et al., 2011), the reduction in working time was obtained on spur pruned cordon, double row spurred and casarsa vines, measuring: pruning times and costs, pruning quality and vegetative-productive response of the vine (Caprara and Pezzi 2013).

Data obtained by Caprara and Pezzi (2013), say that comparing MEC with MAN there is a reduction of 95% of the time required, while with Mm there is a reduction of 47%, while the Mw allowed a reduction of 75%.

Subsequent observations have reconfirmed the reduction of the working time, the MAN required about 75h/ha, while the MEC was about 6.5h/ha (Castaldi e Pezzi, 2014); others study it was compared the mechanical light pruning with traditional manual pruning and it was observed that the mechanical light pruning reduction of pruning costs, up to 40% than MAN (Perez-Bermudez et al., 2008).

The reasons of interest for mechanised pruning systems are different, but cost reduction or optimisation is a common objective (Andersen et al., 1996; Clingeleffer, 1988; Intrieri and Poni, 1995; Shultz and Weyand 2005), considering the scarcity and high cost of specialized hand labour (Cruz et al., 2011). The results suggested the feasibility of MEC with a reduction in manual labour costs and time normally employed and with a gain in performance compared to control.

The operational and economic aspects have generally confirmed those already highlighted by the different experiences and have given very favourable indications for the total or partial application of MEC even in small vineyards, both for the combination of costs and operating times and for the vegetative-productive balance of the plants (Caprara e Pezzi 2013; Castaldi e Pezzi, 2014).

3.3.5.2 Effects of mechanical winter pruning on grape yield and quality

The pruning method has effects both on the physical properties of the grapes and on yield (Caprari e Pezzi 2013; Castaldi e Pezzi, 2014; Holt et al., 2008a; Holt et al., 2008b).

According to some experiences, MEC guarantees a final production with equal yield and quality, compared to MAN (Caprari e Pezzi 2013; Castaldi e Pezzi, 2014).

Generally MEC vineyards produce more than MAN vineyards (Toda, and Sancha, 1999; Freeman and Cullis, 1981; Clingeleffer, 1988; Holt et al., 2008a; Holt et al., 2008b), this is due to a higher bud load (Jackson et al., 1984; Morris et al., 1984). In literature it has been observed that the increase in yield due to the bud load occurs only up to certain levels (Jackson et al., 1984; Morris et al., 1984), which vary fundamentally depending on the variety (Jackson et al., 1984), but with an excessively high number of buds you can also have decreases in production (Fawzi et al., 2015).

The increase in yield is therefore not proportional to the increase in bud load, since due to self-regulation there is a reduction in budburst (Heazlewood et al., 2006), bud fertility (Byrne and Howell et al., 1978) and bunch weight (Bates, 2008).
Among other factors, soil fertility affects the extent in which the self-regulation mechanisms act. The results obtained from the experiences of Botelho et al. (2020c) show that an increase in soil fertility can mitigate self-regulation mechanisms.
Mechanical pruning increases the bunches number (Botelho et al. 2020c; Gatti et al., 2011; Toda and Sancha, 1999; Geller and Kurtural, 2013; Poni et al., 2004) and at the same time it can significantly reduce the bunches weight (Botelho et al., 2004, 2020c; Keller et al., 2004; Toda and Sancha, 1999; Geller and Kurtural, 2013), which is influenced both by the individual grape weight (Keller et al., 2004) and by the number of berries (Clingeleffer, 2009; Zheng et al. 2017).
The result is usually an increase in yield in MEC when compared to MAN, because the increase in the bunch number is more important than the decrease in size and bunch weight (Cruz et al., 2011; Botelho et al., 2020b).
Similar results were also obtained by Freeman and Cullis, (1981); Toda and Sancha, (1999); Intrieri et al., (2011).
Further studies say that mechanically pruned vines compared to those treated manually showed not only a higher yield (by 30%), lower weight of bunches and berries, but also a delayed ripening of the bunches (Perez-Bermudez et al. 2008).
MEC tend to improve the physical properties of the berries (Caprari and Pezzi 2013): increased resistance to pedicel detachment, increased elasticity and skin resistance to breakage (Caprari and Pezzi 2013).
It is important not to underestimate the water state of the soil, Toda and Sancha (1999) have studied the effect of mechanical pruning, in dry conditions, on Grenache, isohydric cultivars, obtaining good results.
In a 4-years work performed in Portugal, significant differences in yield were found only in the year with the lowest water deficit (Botelho et al., 2020b). Freeman et al. (1979) had observed a yield increase with the highest bud load only in irrigated vineyards or in vineyards with vintages where water was not a limiting factor. As already mentioned, MEC vineyards tend to consume more water, so to obtain these benefits it is assumed that the use of irrigation is recommended.
Regarding vigour, MEC vines show a tendency to lose vigours (Lopes et al., 2000; Cruz et al., 2011, Toda and Sancha, 1999; Clingeleffer and Krake, 2002; Cruz et al 2011; Botelho et al., 2012). This result is in close connection with a higher number of shoots per plant which leads to a distribution of carbohydrate availability among several sinks, resulting in lower growth of these (Lopes et al., 2000).
Berries obtained from different prunings could be used as a model to decide the most appropriate pruning which is then related to the production of a final style of wine. Ultimately these decisions

should be applied to single vineyards and for single seasons. All this could be important in order to obtain a well defined berry composition which could lead to the production of the desired wine in the winery (Holt et al. 2008a).

3.3.5.3 Effects of mechanical winter pruning on vegetative activity

Mechanical pruning leads to an increase in bud load, in shoot density and a reduction in the individual shoot weight (Botelho et al., 2020b; Botelho et al., 2020c, Caprari and Pezzi 2013; Cruz et al., 2011; Reynolds and Wardle, 1993; Castro et al., 2010). With increasing nodes the self-regulation of the vine leads to a reduction in budburst, the vines did not show any response of the budburst percentage beyond the threshold of 25 nodes per vine (with a spacing of 0.9 m x 2.5 m) for a density of 4444 plants/ha (Gatti et al., 2011).

The percentage of budburst is lower in MEC due to self-regulation (Keller et al., 2004; Intrieri et al., 2001) but despite this the number of shoots is higher in MEC, in fact, mechanically pruned vines compared to those treated manually showed a tendency to overgrow compared to MAN vines (Perez-Bermudez et al., 2008). The same results were also obtained by other studies (Toda and Sancha, 1999; Clingeleffer and Krake, 2002).

The development of many shoots creates a higher leaf area, especially in the first part of the season (Smithyman et al., 1997), although this difference can be maintained until the end of the cycle (Schmid and Schultz, 2000; Botelho et al., 2012). The increase in leaf area intensifies water consumption, although a certain reduction in transpiration rate per unit leaf area is usually observed (Schmid and Schultz, 2000).

Another effect of mechanical pruning noticed at Cartaxo in Portugal on vineyards planted with Cabernet sauvignon is to have shown a negative leaf water potential at dawn but despite this the photosynthesis activity of adult leaves was unchanged (Lopes et al. 2000).

The pruning weight per vine is normally significantly lower in MEC, since the increase in the number of shoots is less important than the reduction in shoot weight. These results lead to higher Ravaz Index values with MEC, reflecting changes in carbohydrate distribution that are redirected from vegetative to reproductive growth (Botelho et al., 2020b; Botelho et al., 2020c; Poni et al., 2000; Clingeleffer and Krake, 2002; Morris and Cawthon, 1981).

Mechanically pruned vines tend to be more efficient, as they invest less energy in cane formation, redirecting the increased available carbohydrates to reproductive growth and reserve formation (Clingeleffer and Krake, 1992; Weyand and Schultz, 2006).

In order to increase yield and prevent an excessive loss of vigour, it must be provided the right nutritional requirement to maintain an appropriate balance (Botelho et al., 2020a).

Other studies also conducted in Portugal reported that the longevity of the vine (in this study cv. Cabernet Sauvignon) was not compromised (Lopes et al. 2000).

In conclusion, we can say that from the studies carried out so far, mechanized pruning and fertilization with organic soil improvers have had a positive effect both on the number of shoots and clusters per vine, and on the increase in yield, without compromising vegetative growth (Botelho et al. 2020), increasing the profitability of the company.

3.3.5.4 Effects of mechanical winter pruning on relationships among berry weight, berry composition and wine composition

There are two studies, during three-year, on cv. Cabernet Sauvignon in which authors related how mechanical and manual pruning affects berry weight and size, berry chemical composition, and sensory aspects of the wine (Holt et al. 2008a; Holt et al. 2008b).

They confirmed again that the action of pruning modulates both berry size, weight and number, and wine composition. Machine-pruned wines were consistently rated lower in quality than MAN (cane or spur) pruned wines. Berry size was also influenced by vintage which also affected wine quality aspects.

In these studies, positive and/or negative sensory descriptors (chemical, physical and aroma components) were grouped together by evaluating them as a group and examining their influences on overall quality scores.

Wines obtained by mechanical pruning had lower quality scores, in fact contrary to what it is believed smaller berries were not associated to higher quality wines and higher concentrations of anthocyanins, total phenols and tannins in berries were not associated to higher quality wines. Basically concentrations of anthocyanins, phenols and tannins cannot be considered as good indicators of wine quality despite the fact that different vineyard treatments and vintage iinduce important changes in both berry composition and wine quality (Holt et al. 2008b)

The relation between the composition of berries and the composition of wine is not simple and direct, just as it is not between the composition of wine and its sensorial properties or the quality of wine.

In fact it was seen that higher concentrations of tannins and phenols in wine could not be attributed to a higher astringency in wine, therefore the composition of wine was not always directly influenced by the composition of berries.

Differences in quality between pruning treatments were related to changes in berry size and composition, whereas differences in quality between vintages were due to other parameters that composed berries (Holt et al., 2008a; Holt et al., 2008b)

The effects of vintages in the vineyards examined, were more pronounced than the effects obtained by pruning (Holt et al., 2008a).

The relation between wine's composition and its sensorial properties is most likely based on the balance among a certain number of components rather than on the concentration of single components.

The quality of a wine, therefore, will depend not so much on the sum of the single parameters but on the balance relationships among the many quantitative and qualitative parameters of grapes and wine (figure 2).

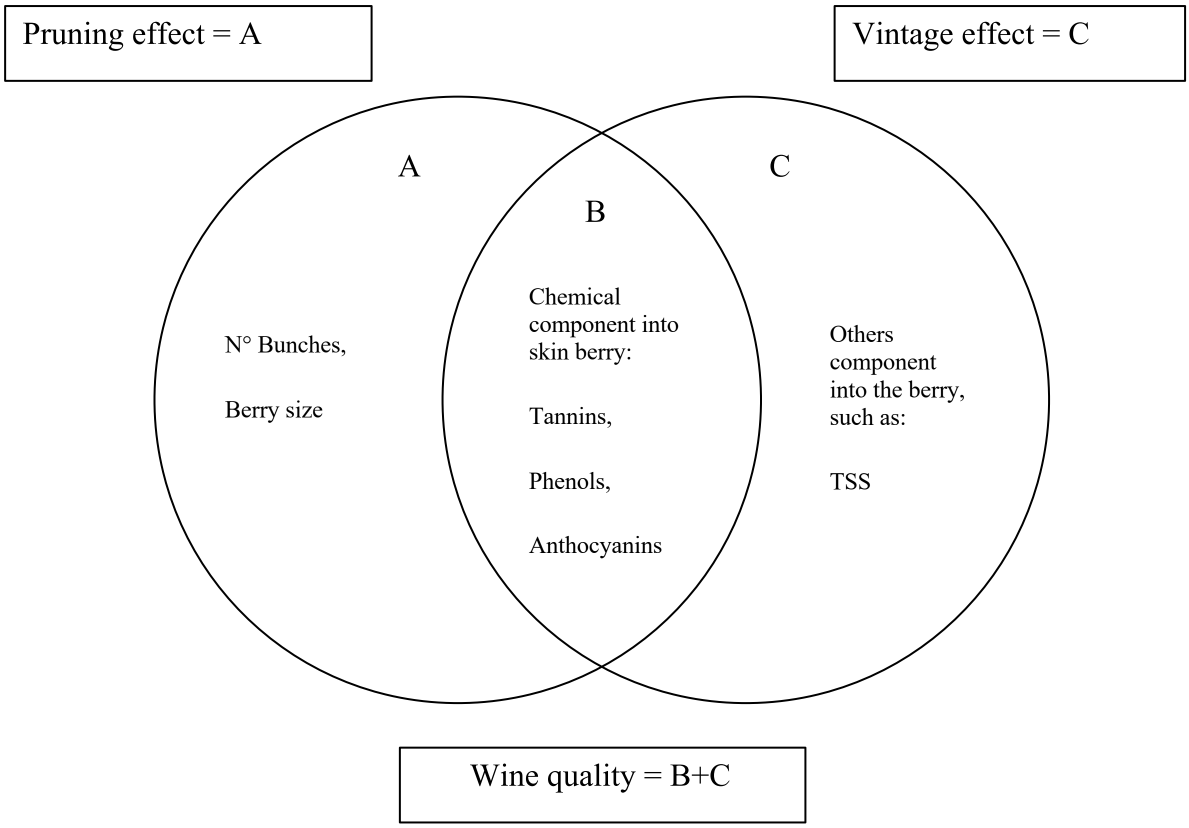


Figure 2 – Hypothetic representation with sets and subsets to obtain a quality wine. (based on Holt et al., 2008a; Holt et al., 2008b) .

In the next years a study that could be proposed is a work with a higher number of vintages where it will be tried to develop a reliable evaluation of the relationships between enological and sensorial viticultural properties as they can be modulated. In fact the cultivation of the vineyard and the conditions of the vintage influence the composition of berries and how they are related to the composition, quality, style of the wine produced (Holt et al., 2008b).

By knowing and managing the different conditions there will be more opportunities to manage not only the viticultural part but also the vinification one therefore producing a wine which is closer to the demands set by the producer.

By considering the data obtained by these studies it is possible to see how in a similar vineyard the wines produced could be of lower quality than the ones produced with vines pruned with a lower number of buds (Holt et al., 2008a; Holt et al., 2008b).

4. Material and Methods

This trial was implemented in 2018. The data obtained in 2020, and presented in this dissertation, correspond to the third year of data collection.

4.1 Vineyard site

The trial was conducted at Quinta do Gradil, located at Vilar, Cadaval municipality, in the Lisbon Wine Region.

A vineyard of *V. vinifera* L. Sauvignon blanc was used. The vines, grafted on SO4 rootstock, were planted in 2005 and spaced 1.0×2.6 m apart, with E-W orientation. The training system is a unilateral Royat cordon, established at 70 cm from the ground, with vertical positioning of the shoots.

The soil of these plots has a sandy-loam texture soil, with a pH of 5.9, a low organic matter content (1.07%), an extractable K content of 167 mg kg^{-1} and an extractable P content of 61 mg kg^{-1}.

This vineyard was not irrigated and it was not applied mineral fertilization, just only MSW in several dosage.

The climate is a Csb, according to the climate classification of Köppen-Geiger (IPMA 2020).

Csb is a temperate climate with dry summers, in which the average temperature of the hottest month is never lower than 22 °C, with a winter month that records at least three times the precipitation of the driest summer month never lower than 30 mm, and with at least 4 months of average temperature above 10 °C.

4.2 Experimental layout

The experiment was established in a strip-plot design, with 4 blocks and the following studied factors:

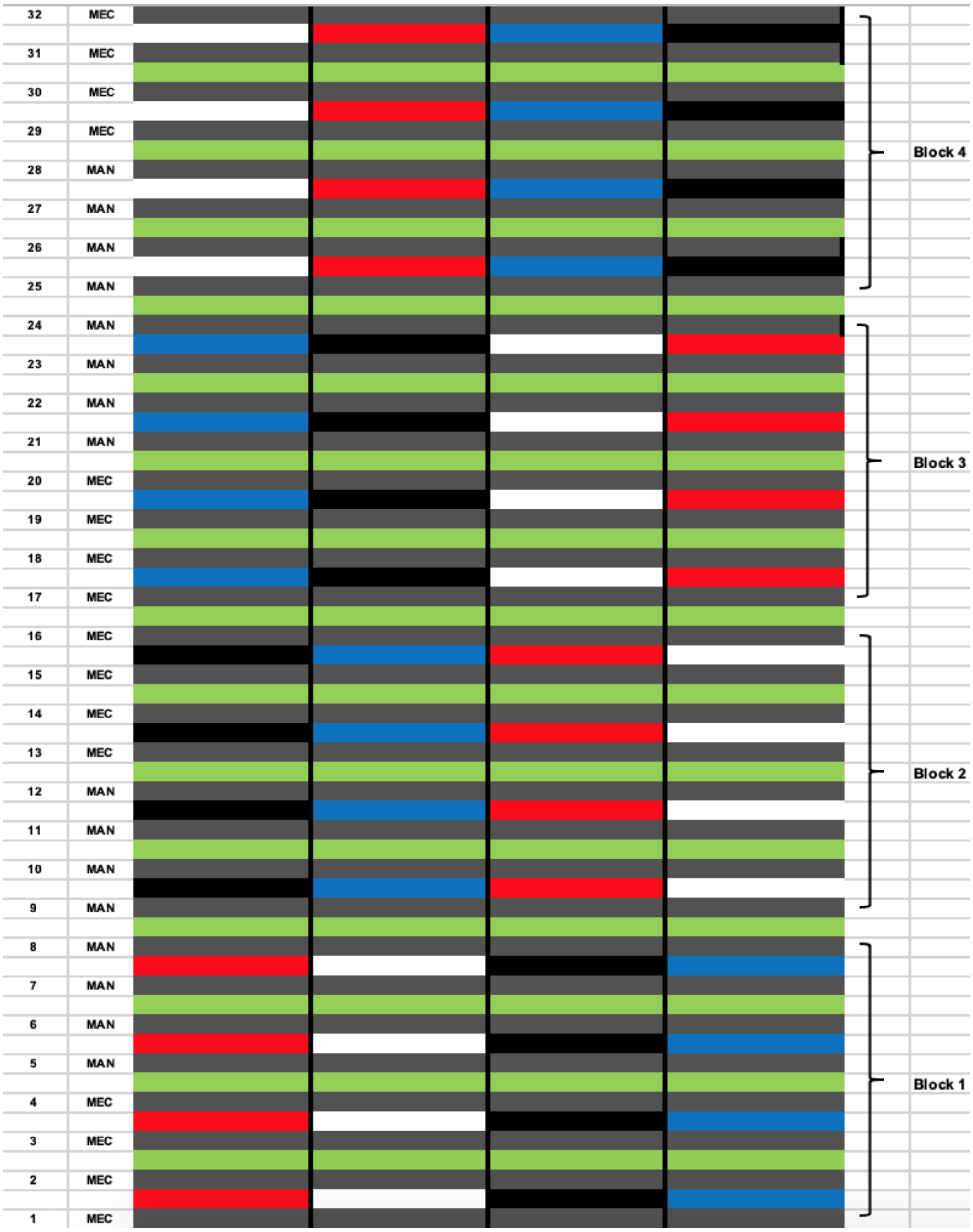
- pruning system, with 2 levels, manual pruning (MAN) and mechanical pruning (MEC);
- dose of municipal solid waste compost, with 4 level, 0 (Ctrl), 5000 (M1), 10000 (M2) and 20000 (M3) kg/ha.

In the strip-plot design (figure 5):

- the “pruning system” was the vertical strip plot, established in the vine rows;
- the “dose of municipal solid waste compost” was the horizontal strip plot, established in strips perpendicular to the vine rows orientation.

Each block contains 8 adjacent rows, where the pruning treatment was randomly assigned, thus creating two groups of four adjacent rows each, with a different pruning treatment (4 rows MAN and 4 rows MEC pruning).

The rows were divided in four strips, of twelve meters each, where the different doses of MSW compost were randomly applied. The organic amendments were spread in alternated interrows, creating a strip perpendicular to the row orientation (figure 3). Each of the 32 plots consisted of 48 vines.



	Dosage (kg ha^{-1})	Colour
M1	5000	Red
M2	10000	Blue
M3	20000	Black
Ctrl	0	White

Figure 3 - Experimental layout

4.3 Pruning systems

The pruning treatments were the following: MAN - spur pruning, maintaining six to seven spurs with 2 buds per vine; or with mechanical method; MEC - performed by a machine with four cutting bars, 2 parallel and 2 perpendicular to the ground, all operating at 15 cm from the cordon; all the wood with ventral insertion was manually removed.

In the MAN treatment, the training system was a Royat cordon, established at 70 cm above the soil surface, with vertical positioning of the vegetation. The movable wires were moved once in the season (just before blooming) to position the shoots, which were then cut to create a parallelepipedic canopy.

In the MEC treatment, the cordon was still established 70 cm above the soil surface and the wires remained in the same position (40 cm and 80 cm above the cordon) throughout the year, and the shoots were not positioned. Thus, some shoots grabbed their tendrils from the wires and kept a vertical position, while the others grew freely in an oblique or horizontal position, creating a larger and sparse canopy. The management of the canopy, in MEC, was limited to the light and wide mechanical trimming of the shoots carried out to promote vertical growth and optimal conditions for harvesting and subsequent winter pruning. The shoots were tipped before blooming and veraison to retain about 9-10 leaves on the main shoots.

4.4 MSW compost doses

Regarding the MSW compost, four treatments have been set, corresponding to the following doses:

- **Ctrl**, no application of MSW compost (white);
- **M1**, application of 5000 kg ha^{-1} year^{-1} of MSW compost (red);
- **M2**, application of 10000 kg ha^{-1} year^{-1} of MSW compost (blue);
- **M3**, application of 20000 kg ha^{-1} year^{-1} of MSW compost (black);

The mean composition of the MSW compost is presented in table 3.

Table 3 – Composition of the MSW compost

Fertilizer's Characteristic	**Unit**	**Value**
pH		7.71
Elettrical conductivity	mS m^{-1}	413.0
Moisure	%	44.20
Dry matter basis		
Organic Matter	%	46.5 ± 10.03
Total N	%	2.1 ± 0.16
Total P	g kg^{-1}	6.9 ± 0.46
Total K	g kg^{-1}	7.8 ± 0.25
Total Ca	g kg^{-1}	72.7 ± 18.00
Total Mg	g kg^{-1}	14.9 ± 3.04
Total S	g kg^{-1}	2.9 ± 0.16
Total Na	g kg^{-1}	6 ± 2.65
Total Fe	g kg^{-1}	8 ± 0.08
Total Mn	mg kg^{-1}	249.9 ± 0.02
Total Cu	mg kg^{-1}	132.2 ± 0.08
Total Zn	mg kg^{-1}	360.8 ± 0.02
Total B	mg kg^{-1}	26.1 ± 0.93
Total Ni	mg kg^{-1}	10 ± 0.01
Total Cd	mg kg^{-1}	0.03 ± < 0.01
Total Pb	mg kg^{-1}	79.6 ± 0.07
Total Cr	mg kg^{-1}	27.8 ± 0.03
Total Hg	mg kg^{-1}	0.41 ± 0.29

Fertilizer is applied every year and the data presented refersto the third year.
The MSW compost was applied in alternated interrows (to maintain one interrow with no soil mobilization), spread over the soil and incorporated with a slight disc harrowing before sprouting.

4.5 Reproductive and vegetative growth

In order to determine the yield components, the number of bunches per vine and their weight were assessed at harvest time. In each experimental unit the production of 4 previously selected vines was evaluated, consisting in 32 vines per block.
The Covid lockdown limited the collection of data regarding leaf area, canopy structure and ecophisiology.

4.6 Grape composition

The probable alcohol content (PAC), pH, total acidity and yeast assimilable N of the grapes were evaluated through the laboratory analysis of 8 samples of the 100 grapes per treatment. These analyses were performed followed the method of analysis proposed by OIV 2019.

4.7 Statistical Analysis

The data were tested to verify whether the hypotheses of variance analysis (ANOVA) were met using the Shapiro-Wilk test, and then subjected to two-way ANOVA (pruning × MSW compost dose), using the general linear procedure for the strip-plot design and F-test.

The level of significance was set at $\alpha = 0.05$ and the media were separated using Tukey's significant difference test.

The statistical analysis was performed using the software package Statistix (version 9.0; Analytical Software, Tallahassee, FL, USA).

5. Results

5.1 Bunch number

Pruning system affected significantly the number of bunches per vine. Number of bunches per vine increased from 24,9 in manual pruning (MAN) to 37,1 in mechanical pruning (MEC), corresponding to an increase of 33% in the number of bunches per vine (Table 4).

The interaction between factors (pruning system x dose of MSW compost) was not significant.

Table 4: Pruning system and organic amendment effect in number of bunches, weight of bunches and yield.

	Nº Bunches	Weight/Bunch (g)	Yield (kg/ha)
MAN	24.9	131.1	13100
MEC	37.1	124	17800
Sig	*	n.s.	*
M1	29.3	121.5	14100
M2	34.9	127.4	18000
M3	29.3	123.2	14100
Ctrl	30.7	138.2	15700
Sig	n.s.	n.s.	n.s.
Pruning x MSWC	n.s.	n.s.	n.s.

[1] Significance level (Sig.): n.s.—non-significant at $p < 0.05$ level by F test; significant at $p < 0.05$ (*), $p < 0.01$ (**) and $p < 0.001$ (***) by F test. In each column values followed by the same letter do not significantly differ by Tukey HSD test at $\alpha = 0.05$. Pruning system: hand pruning (MAN) and mechanical pruning (MEC). Municpal Solid wast compost doses (MSWC): Ctrl (no application), M1 (5000 kg/ha), M2 (10000 kg/ha), M3 (20000 kg/ha).

5.2 Bunches weight

The bunch weight was not affected by the pruning treatment, although it showed a tendency to obtain a lower value in MEC (Table 4).

Regarding the effect of the organic fertilization to the soil, no significant differences were observed between MSW compost doses.

The interaction between factors (pruning system x dose of MSW compost) was not significant.

5.3 Yield

Pruning system affected significantly vines yield (Table 4). Yield increased from 13100 kg/ha in manual pruning (MAN) to 17800 kg/ha in mechanical pruning (MEC), corresponding to an increase of 26% in yield.

Regarding the organic fertilization, although it was the third year of application of MSWC, yield was not significantly affected by the dose of MSW compost (Table 4).

The interaction between factors (pruning system x dose of MSW compost) was not significant.

5.4 Grape composition

The analysis of the obtained data, showed that pruning system had a significant effect on grape composition, namely, probable alcohol content (PAC), pH and total acidity (Table 5).

PAC increased, significantly, from 13.06 in manual pruning to 13.32 in mechanical, while pH also increased from 2.99 to 3.06, respectively in manual and mechanical pruning. Despite being statistically significant, these differences, from the agronomic and enological point of view, are not relevant.

On the contrary, total acidity decreased from 6.21 in manual pruning to 5.71 in mechanical pruning.

Dose of MSW compost did not affect PAC, pH and total acidity, but had a significant effect on yeast assimilable N. Treatments that received MSW compost, tend to have grapes with high values of yeast assimilable N, with M1 (5000 kg/ha) being statistically higher than the Ctrl treatment (no MSW compost application).

The interaction between pruning system and dose of MSW compost was not significant in any of the analyzed parameters.

Table 5 – Effect of pruning system and MSW compost dose on probable alcohol content (PAC), pH, total acidity, and assimilable N (assim N) of grapes.

Line Labels	**PAC (% vol.)**	**pH**	**Total acidity (g/L)**	**assim N (mg/L)**
MAN	13.06	2.99	6.21	107.73
MEC	13.32	3.06	5.71	99.53
Sig	*	*	*	n.s.
M1	13.21	3.03	5.95	109.38 a
M2	12.98	3.01	5.88	105.00 ab
M3	13.24	3.04	6.04	107.19 ab
Ctrl	13.34	3.02	5.96	92.97 b
Sig	n.s.	n.s.	n.s.	*
Pruning X MSWC	n.s.	n.s.	n.s.	n.s.

[1] Significance level (Sig.): n.s.—non-significant at $p < 0.05$ level by F test; significant at $p < 0.05$ (*), $p < 0.01$ (**) and $p < 0.001$ (***) by F test. In each column values followed by the same letter do not significantly differ by Tukey HSD test at α = 0.05. Pruning system: hand pruning (MAN) and mechanical pruning (MEC). Municpal Solid wast compost doses (MSWC): Ctrl (no application), M1 (5000 kg/ha), M2 (10000 kg/ha), M3 (20000 kg/ha).

6. Discussion

Unfortunately, due to the lockdown it was not possible to evaluate leaf area, canopy structure and leaf gas exchanges which, as we know, are in close connection with the reproductive growth and grape composition.

6.1 Number of bunches

The mechanically pruned plants, as already mentioned, produced more bunches. In fact, as reported in the literature (Botelho et al., 2020c; Gatti et al., 2011; Toda and Sancha 1999; Geller and Kurtural, 2013; Poni et al., 2004) it is widely shown that in mechanical pruning, compared to manual pruning, a higher number of buds is left: this will lead to an increase in the number of bunches and, almost always, to an increase in yield.

In this study, the dose of MSW compost did not lead to significant differences in the number of bunches, although with the application of 10000 kg/ha (M2), there was a tendency to increase. Probably, if the same doses of MSW compost continue to be applied in the coming years, a significant increase may occur, as referred by Botelho et al. (2020c). Although in the referred study, an increase is reported from the third year.

6.2 Cluster weight

The analysis of the obtained data, showed that the cluster weight was not significantly affected by the pruning system.

However, there was a downward trend in the weight of the grapes in the vines pruned mechanically. Similar results were obtained by Botelho et al. (2020c), Keller et al. (2004), Toda and Sancha (1999), Geller and Kurtural (2013), Clingeleffer (2009), and Botelho et al. (2020b). Focusing on fertilization, it can be seen that the weight of the bunches was not affected by the dose of MSW compost. Also in the studies conducted by Liu et al. (2016), in vineyards fertilized with organic fertilizer such as sludge and/or MSW, variations in bunch weight were not significant for vineyards treated with MSW compost.

In conclusion, the weight of the bunches was not influenced by any studied factor, since neither the pruning system nor the dose of MSW compost significantly changed the values.

6.3 Yield

From the overall analysis of the data obtained in the present work, the yield was significantly affected by the pruning system. The higher yield was obtained in the mechanical pruning. The same result was also found by several other authors (Clingeleffer 1984; Lopes et al. 2000, Castro et al. 2010) but, in several papers, the increase in yield was not significant in all vintages (Toda and Sancha 1999; Clingeleffer 1988, Freeman and Cullis 1981).

Mechanical pruning, as mentioned above, leaves a higher number of buds on the plant than manual pruning, so the number of bunches increases significantly. Considering that the bunch weight did not decrease significantly, yield is directly affected by the number of bunches and, therefore, is higher in the mechanical pruning. The higher bud load is the main reason for the yield increase in fully mechanized pruning systems.

Analyzing the obtained data, it has been seen that the MSW supplied to the soil, until the third year, did not led to significant differences in yield. However, it is possible to see that in the vines treated with 10000 kg/ha (M2) the absolute value of the yield was higher. This may suggest that in the following years, a significant increase in yield may be observed. If this does not happen, the results obtained would agree with those of Pinamonti (1998) and Morlat (2008).

In order to better evaluate the data obtained in the field, MSW compost should be applied during more years, before having the certainty of the result.

According to the literature, bud load is influenced by the pruning method. In mechanical pruning there is an increase in the bud load of the plant (Toda and Sancha, 1999; Clingeleffer and Krake, 2002), which will respond with lower budburst percentage, due to self-regulation mechanisms (Keller et al., 2004; Intrieri et al., 2001). However, it has been demonstrated that if the vineyard is fertilized, it determines an increase in budburst percentage, with a consequent increase in shoot number, which consequently increases the number of bunches and yield (Botelho et al.2020c). Clearly the starting budload must be within certain limits, in fact over a certain number of budloads there may be risks of yield and grape quality losses (Jackson et al., 1984; Fawzi et al., 2015).

Still, in according to literature, the fastest response in yield has been recorded following the application of sludge, compared to both MSW and manure, this is probably due to their higher N content (Botelho et al 2020b). It is therefore noted that the results are quite variable from case to case.

It can be assumed that the amount of MSW administered in this study was not high enough to achieve an effect in just three years, since the amount of N in mineral and/or mineralized form was not sufficient.

There were, also, no significant differences in the interaction between pruning system and MSW compost dose. Again, it is possible to assume that the amount of N provided by the MSW is not able to change the yield in synergy with the benefits offered by the MEC. Studies conducted in Portugal have shown that improving soil fertility can mitigate self-regulation mechanisms and increase yield in mechanically pruned vines (Cruz et al. 2011).

6.4 Chemical composition of grapes

Mechanical pruning not only leads to an increase in yield, but can also lead to a change in the chemical composition of the grapes (Intrieri et al., 2011; Terry and Kurtural, 2011).

In our study, grapes from mechanically pruned vines had a slightly higher probable alcohol content (PAC) and pH and a lower total acidity, when compared to manual pruning. These results, if reconfirmed, provide an additional tool on the choice of the agronomic techniques to be used, depending on the oenological product we want to obtain.

From the analysis of the obtained data, MSW compost doses affected the yeast assimilable N in grapes. MSW compost has nitrogen in its composition (2.1% on the dry weight basis), and the amount of N released by the compost may had affected the values of assimilable N in grape, even more quickly than the effect on the yield.

In different regions the administration of a different amount of N/year may be sufficient, while in other regions the same amount may be insufficient due, for example, to a different environment (warmer, drier and/or less fertile).

A sandy-loam soil, like that of Quinta do Gradil, despite having an adequate texture to vineyards, has a reduced fertility, due to the low level of organic matter. The result obtained was only partially improved by the organic fertilization. In fact, despite the increase of yeast assimilable N brought by the organic fertilization, this value was however below the probable threshold (140 mg/L of assimilable N) necessary to complete the fermentation in a reasonable period of time (Beltran et al, 2005; Bely et al., 1990; Bisson, 1999; Henschke and Jiranek, 1993; Jiranek et al., 1995; Kemsawasd et al., 2015), depending on sugar concentration and winemaking practices.

7. Conclusions and further work

This work showed that mechanical pruning has significantly increased the number of bunches, without changing their weight, but increasing the yield per plant. The vineyard studied did not have irrigation systems and showed a good yield even in dry conditions.

Mechanical pruning affected, also, grapes composition. Grapes from mechanically pruned vines showed a higher probable alcohol content (PAC), a slightly higher pH and a lower total acidity, when compared to manual pruning.

The only effect shown by fertilization with MSW compost concerns the increase of assimilable nitrogen in the grapes.

The study has some limitations due to the lack of available data that make it partially incomplete, in particular, as already mentioned, the foliar surface, foliage structure and foliar gas exchange that were not evaluated. These parameters are closely related to the reproductive growth and composition of the grapes. Among the weak points of the work, stands out the insufficient duration of the observation, especially with regard to organic fertilization with MSW compost. In order to better define the potential of organic fertilization with MSW compost, a longer period of time is necessary in order to obtain definitive and more reliable results.

The research on MSW fertilizers is quite innovative, in fact the previous studies were oriented on other types of organic fertilizers and provided more results due to the longer period of observation. The particular attention on organic waste derived from urban residues will have to be standardized both as quantity to be administered per hectare and for the quality of the substance, in order to obtain comparable values over time.

The values already found in this season with different doses of MSW have shown that organic fertilization has not influenced the quantitative aspects of production if not the amount of assimilable nitrogen present in the berry.

Fertilization presupposes a higher productivity both from the quantitative and qualitative point of view for plants; in the present work the amount of nutrients released from compost in the soil has not led to the expected improvements, this may also be due to the low amount of organic matter already present in the soil (1.07% soil organic matter) or the low amount of minerals released, such as N.

Surely the study should continue taking into account the dosage and type of MSW necessary to achieve abundant, quality harvests that show the effects in the shortest possible time.

In this study, it is reported that the interaction between the two types of treatment did not provide any significant change in the number of bunches, weight, yield or quality of the grapes.

One of the future challenges, as already mentioned by other authors, is to use a compost obtained from certified quality urban waste in order to gain the trust of farmers and achieve the objectives set; this will lead to benefits both in environmental and economic terms, as well as greater sustainability in the exploitation of resources.

Although the study has not shown significant results for any of the parameters considered during the year of work, the effects of mechanical pruning and the use of MSW observed in previous studies show an increase in yield. Therefore, the study at Quinta do Gradil may provide additional help to the literature. It will be necessary to continue with studies of this type, given the multiplicity of positive effects both, in particular, on the yield of the vineyard and in general, on the sustainable use of resources.

ANNEX

Table 6 - Complete table with the results obtained (number of bunches, bunch weight and yield) in each individual by the different treatments (pruning and fertilization)

N Plant	Block	Pruning	A.O.	Bunches	Bunches Weight	Yield
1	1	MEC	M2	46	146,74	25,96
2	1	MEC	M2	39	133,33	20,00
3	1	MEC	M2	48	164,58	30,38
4	1	MEC	M2	24	91,67	8,46
5	1	MEC	M3	42	88,09	14,23
6	1	MEC	M3	43	106,98	17,69
7	1	MEC	M3	28	108,93	11,73
8	1	MEC	M3	26	134,61	13,46
9	1	MEC	TEST	25	134,00	12,88
10	1	MEC	TEST	29	155,17	17,31
11	1	MEC	TEST	45	140,00	24,23
12	1	MEC	TEST	35	101,43	13,65
13	1	MEC	M1	38	114,47	16,73
14	1	MEC	M1	49	102,04	19,23
15	1	MEC	M1	12	87,50	4,04
16	1	MEC	M1	28	87,50	9,42
17	1	MAN	M2	22	125,00	10,58
18	1	MAN	M2	21	157,14	12,69
19	1	MAN	M2	12	54,17	2,50
20	1	MAN	M2	9	77,78	2,69
21	1	MAN	M3	24	154,17	14,23
22	1	MAN	M3	28	158,93	17,12
23	1	MAN	M3	23	58,70	5,19
24	1	MAN	M3	25	56,00	5,38
25	1	MAN	TEST	27	155,56	16,15
26	1	MAN	TEST	13	192,31	9,62
27	1	MAN	TEST	25	164,00	15,77
28	1	MAN	TEST	9	116,67	4,04
29	1	MAN	M1	32	135,94	16,73
30	1	MAN	M1	7	42,86	1,15
31	1	MAN	M1	10	40,00	1,54
32	1	MAN	M1	14	78,57	4,23
33	2	MAN	TEST	41	96,34	15,19
34	2	MAN	TEST	8	137,50	4,23
35	2	MAN	TEST	23	173,91	15,38
36	2	MAN	TEST	28	139,29	15,00
37	2	MAN	M1	34	166,18	21,73
38	2	MAN	M1	20	122,50	9,42
39	2	MAN	M1	33	127,27	16,15
40	2	MAN	M1	21	138,10	11,15
41	2	MAN	M2	16	53,13	3,27
42	2	MAN	M2	57	128,95	28,27
43	2	MAN	M2	19	107,89	7,88
44	2	MAN	M2	33	151,52	19,23
45	2	MAN	M3	7	135,71	3,65
46	2	MAN	M3	27	166,67	17,31
47	2	MAN	M3	24	68,75	6,35
48	2	MAN	M3	17	50,00	3,27
49	2	MEC	TEST	47	80,85	14,62
50	2	MEC	TEST	37	86,49	12,31
51	2	MEC	TEST	16	143,75	8,85
52	2	MEC	TEST	7	142,86	3,85
53	2	MEC	M1	49	93,88	17,69
54	2	MEC	M1	52	120,19	24,04
55	2	MEC	M1	31	180,65	21,54
56	2	MEC	M1	31	98,39	11,73
57	2	MEC	M2	54	137,04	28,46
58	2	MEC	M2	40	130,00	20,00
59	2	MEC	M2	45	100,00	17,31
60	2	MEC	M2	49	145,92	27,50
61	2	MEC	M3	33	166,67	21,15
62	2	MEC	M3	30	138,33	15,96

63	2	MEC	M3	13	123,08	6,15
64	2	MEC	M3	27	75,93	7,88
65	3	MAN	M1	52	130,77	26,15
66	3	MAN	M1	31	151,61	18,08
67	3	MAN	M1	41	152,44	24,04
68	3	MAN	M1	34	138,24	18,08
69	3	MAN	TEST	30	171,67	19,81
70	3	MAN	TEST	25	74,00	7,12
71	3	MAN	TEST	22	125,00	10,58
72	3	MAN	TEST	25	124,00	11,92
73	3	MAN	M3	18	144,44	10,00
74	3	MAN	M3	36	138,89	19,23
75	3	MAN	M3	28	155,36	16,73
76	3	MAN	M3	41	126,83	20,00
77	3	MAN	M2	41	146,34	23,08
78	3	MAN	M2	24	145,83	13,46
79	3	MAN	M2	30	136,67	15,77
80	3	MAN	M2	15	83,33	4,81
81	3	MEC	M1	19	128,95	9,42
82	3	MEC	M1	19	134,21	9,81
83	3	MEC	M1	20	110,00	8,46
84	3	MEC	M1	21	157,14	12,69
85	3	MEC	TEST	41	112,20	17,69
86	3	MEC	TEST	63	126,98	30,77
87	3	MEC	TEST	52	128,85	25,77
88	3	MEC	TEST	49	144,90	27,31
89	3	MEC	M3	41	173,17	27,31
90	3	MEC	M3	32	153,13	18,85
91	3	MEC	M3	41	126,83	20,00
92	3	MEC	M3	38	102,63	15,00
93	3	MEC	M2	31	166,13	19,81
94	3	MEC	M2	51	152,94	30,00
95	3	MEC	M2	48	122,92	22,69
96	3	MEC	M2	34	73,53	9,62
97	4	MEC	M3	28	135,71	14,62
98	4	MEC	M3	49	136,73	25,77
99	4	MEC	M3	33	122,73	15,58
100	4	MEC	M3	19	94,74	6,92
101	4	MEC	M2	30	115,00	13,27
102	4	MEC	M2	59	137,29	31,15
103	4	MEC	M2	53	132,08	26,92
104	4	MEC	M2	68	120,59	31,54
105	4	MEC	M1	26	76,92	7,69
106	4	MEC	M1	37	127,03	18,08
107	4	MEC	M1	46	123,91	21,92
108	4	MEC	M1	31	158,06	18,85
109	4	MEC	TEST	53	135,85	27,69
110	4	MEC	TEST	56	110,71	23,85
111	4	MEC	TEST	44	110,23	18,65
112	4	MEC	TEST	27	122,22	12,69
113	4	MAN	M3	41	151,22	23,85
114	4	MAN	M3	19	73,68	5,38
115	4	MAN	M3	18	191,67	13,27
116	4	MAN	M3	38	123,68	18,08
117	4	MAN	M2	4	100,00	1,54
118	4	MAN	M2	48	191,67	35,38
119	4	MAN	M2	23	208,70	18,46
120	4	MAN	M2	24	137,50	12,69
121	4	MAN	M1	29	117,24	13,08
122	4	MAN	M1	14	175,00	9,42
123	4	MAN	M1	22	136,36	11,54
124	4	MAN	M1	33	133,33	16,92
125	4	MAN	TEST	14	207,14	11,15
126	4	MAN	TEST	4	125,00	1,92
127	4	MAN	TEST	25	240,00	23,08
128	4	MAN	TEST	37	202,70	28,85

Table 7 - Complete table with the results obtained (PAC, pH, tot.acidity and ass N) in each individual by the different treatments (pruning and fertilization)

Block	Pruning	A.O.	ºprobable	pH	Total Acidity	Assimilable N (mg/L)
1	MAN	TEST	12,50	2,90	7,65	122,50
1	MAN	M1	12,75	2,97	6,45	78,75
1	MAN	M2	13,06	3,00	5,85	122,50
1	MAN	M3	13,25	2,98	6,23	113,75
1	MEC	TEST	13,44	3,04	5,78	52,50
1	MEC	M1	13,75	3,07	5,85	140,00
1	MEC	M2	13,00	3,00	5,48	96,25
1	MEC	M3	13,25	3,04	5,85	105,00
2	MAN	TEST	13,44	2,97	6,00	113,75
2	MAN	M1	13,06	2,96	6,15	113,75
2	MAN	M2	12,75	2,96	6,08	105,00
2	MAN	M3	13,69	3,04	6,30	122,50
2	MEC	TEST	13,63	3,05	5,33	70,00
2	MEC	M1	13,44	3,08	5,55	96,25
2	MEC	M2	13,13	3,06	5,78	113,75
2	MEC	M3	13,38	3,08	5,93	87,50
3	MAN	TEST	13,63	2,99	6,00	78,75
3	MAN	M1	12,94	2,97	5,93	122,50
3	MAN	M2	12,69	3,00	6,23	122,50
3	MAN	M3	12,56	3,00	6,53	105,00
3	MEC	TEST	13,69	3,08	5,48	140,00
3	MEC	M1	13,50	3,05	5,78	105,00
3	MEC	M2	13,13	3,05	5,78	96,25
3	MEC	M3	12,81	3,08	6,00	105,00
4	MAN	TEST	13,38	3,07	5,55	61,25
4	MAN	M1	13,19	3,08	6,15	113,75
4	MAN	M2	12,69	2,98	6,30	105,00
4	MAN	M3	13,38	3,01	5,93	122,50
4	MEC	TEST	13,00	3,02	5,93	105,00
4	MEC	M1	13,06	3,07	5,78	105,00
4	MEC	M2	13,38	3,06	5,55	78,75
4	MEC	M3	13,63	3,09	5,55	96,25

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