Organic amendments application to soil of mechanically pruned vineyards: effects on yield and grape composition of cultivar 'Syrah' (*Vitis vinifera* L.)

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Abstract

The effect of three different soil organic amendments on vine performance and wine quality of mechanically box pruned vineyards was evaluated from 2012 until 2015. Two field trials, with a randomized complete block design, were established on 'Syrah' vineyards at Quinta do Côro (QC) and Quinta do Gradil (QG), Tejo and Lisboa wine regions respectively. Organic amendments – municipal solid waste compost (MSWC) and cattle manure (Manure) – were applied annually, in an amount corresponding to 5000 kg of dry organic matter per hectare. In year 1 (2012) no effects were found. In the following years Manure and MSWC originated higher yields than Control (Ctrl). In year 2 those differences were associated with the cluster weight, while in years 3 and 4 both the number of clusters per vine and their individual weight concurred for the higher yields observed. The pruning weight per vine was higher in Manure, comparing to Ctrl, in years 2 and 3. Manure and MSWC increased the vine total dry matter production. Regarding to grape composition, analyzed in years 2 and 3, globally, MSWC and Manure showed no significant differences when compared to Ctrl. MSWC and Manure improved yield without significant quality loss, proving to be good options for increase vineyard profitability.

Keywords: grapevine, climate changes, soil organic matter, municipal solid waste compost, cattle manure, quality

INTRODUCTION

In Europe, vineyard is one of the agricultural ecosystems with the lowest carbon content in the soil (Longbottom and Petrie, 2015) and the one with the highest risk of erosion (Kosmas et al., 1997). The decrease of carbon content in vineyard soils is intensified in Mediterranean regions, due to climatic conditions, namely high temperatures associated with large periods of drought, during late spring and summer, which will worsen with the expected climate changes (Fraga et al., 2012). In a climate change scenario, Mediterranean viticulture is facing serious risks and adaptation measures are needed, in order to face this problem. Among those measures, organic fertilization of soil is highlighted (Fraga et al., 2012) because organic matter plays a fundamental role in long-term soil conservation and/or restoration by sustaining its fertility, due to the improvement of physical, chemical and biological properties of soils (Santos, 2012).

The source of organic matter traditionally used in Portuguese viticulture is cattle and poultry manure. However, available sources of organic matter are increasing, such as composted municipal solid waste, which, if used in agriculture, can improve the physical properties of the soil and provide essential nutrients to plants (Amlinger et al., 2003).

In what concerns to plant vigour, some authors report that the mechanically pruned vines show a tendency to lose vigour, after some years, (Lopes et al., 2000; Cruz et al., 2011) which is, in part, related with the low soil fertility, especially low levels of organic matter. So, the aim of this work is to evaluate the effects of the application of organic amendments on

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mechanically pruned vineyards, in order to increase yield and prevent excessive vigour loss.

MATERIALS AND METHODS

The trial, that ran over four years (2012 to 2015), was installed in two vineyards of *Vitis vinifera* L. 'Syrah'. Quinta do Côro (QC) experimental site is located in Tejo wine region and the vineyard had been grafted on 99R in 1999 and spaced 1.0×2.5 m. In Quinta do Gradil (QG) experimental site, which is located at Lisboa wine region, the vines, grafted on 1103P, were planted in 2005 and spaced 1.0×2.6 m. The cordon was established at 70 cm above soil surface and box pruned.

The studied factor is the organic amendment and three treatments were imposed in a randomized complete block design, with three blocks of 48 vines in each trial field:

- Ctrl – no application of organic amendment neither fertilizer;
- MSWC – application of 16400 kg ha^{-1} $year^{-1}$ of municipal solid waste compost;
- Manure – application of 24800 kg ha^{-1} $year^{-1}$ of cattle manure.

The referred quantity of each organic amendment is expressed in fresh weight and its definition was based on the application of 5000 kg of dry organic matter per hectare and per year. The organic amendments were spread over the soil and incorporated with a light disk harrow, before bud burst. The nutrients supplied by each organic amendment are the following:

- MSWC – 34.4 kg ha^{-1} yr^{-1} of N, 113.2 kg ha^{-1} yr^{-1} of P and 127.9 kg ha^{-1} yr^{-1} of K;
- Manure – 59.5 kg ha^{-1} yr^{-1} of N, 104.2 kg ha^{-1} yr^{-1} of P and 446.4 kg ha^{-1} yr^{-1} of K.

In order to determine yield components, the number of clusters per vine and their weight were assessed at harvest. In each treatment, the production of 36 previously selected vines was evaluated. During pruning, in the same 36 vines, the number of canes per vine and their weight was measured, in order to evaluate the effect of the different treatments on vegetative growth. The dry matter production was calculated as proposed by Carbonneau and Cargnello (2003): DMP=0.2 * yield + 0.5 * pruning weight. The grape composition was assessed by the laboratorial analysis of 6 samples of 100 berries per treatment to determine: probable alcoholic content (PAC); pH; total acidity; anthocyanins content and total phenols.

Statistical analysis was done, using the software Satistix 9, by one-way analysis of variance (ANOVA), using the general linear model, and F test. Since the experimental site interaction with the organic amendment was never significant, its values are not presented.

RESULTS AND DISCUSSION

In Table 1 are presented the yield components along the four years of the trial. Organic amendments increased the number of clusters per vine since year 3 and cluster weight since the year 2 and, in result, yield has been higher in these treatments since the second year of the experiment. Increases in yield, with the application of cattle manure and MSWC, were also found by Conradie (2001), Messiga et al. (2016), Gaiotti et al. (2017) and Ramos (2017). On the other hand, Pinamonti (1998) observed no differences in productivity with a MSWC amendment, as well as Morlat (2008) with a 28-year application of 10 t ha^{-1} yr^{-1} of cattle manure.

Since the N quantity that MSWC supply to the plants is clearly inferior to the one that Manure does (42% less), it would be expected a higher yield in Manure, even because its level is below the one that Spayd et al. (1993) refer as the limit until where yield increases with increasing N supply - 56 kg N ha^{-1}. However, no differences were observed between yield of the two organic amendments. This result is possibly related to a higher stability of N in MSWC than in Manure and, as a consequence, less losses to the environment and greater usage by the vines.

Vine growth (Table 2) was less affected by the organic amendments than yield components. In what concerns to the number of shoots per vine, it was not influenced by the organic amendments and shoot weight was increased only in the year 2. Although the number of shoots per vine was not significant different between treatments, in any year, in an overall analysis there is a significant difference between Ctrl and the other two treatments. The pruning weight per vine was increased by Manure, when compared to Ctrl, in years 2 and 3, while MSWC had an intermediate behavior. Pinamonti (1998), Conradie (2001) and Gaiotti et al. (2017) found similar results.

Table 1. Yield components of 'Syrah' vines subjected to the application of municipal solid waste compost (MSWC) and cattle manure (Manure). A control (Ctrl) with no application of organic amendments was considered. Data are means of 36 vines from both experimental sites. The interaction between organic amendments and experimental site was never significant.

	Clusters vine^{-1}				Cluster weight (g)				Yield (t ha^{-1})			
Year	1	2	3	4	1	2	3	4	1	2	3	4
Ctrl	54	68	64 b	68 b	90	61 b	88 b	70 b	19	17 c	23 b	19 b
MSWC	59	67	78 a	86 a	99	76 a	101 ab	86 a	22	20 b	32 a	29 a
Manure	61	71	75 a	88 a	100	84 a	104 a	85 a	24	24 a	32 a	29 a
Sig.	n.s.	n.s.	**	**	n.s.	**	*	*	n.s	***	**	*

Sig. – Significance level; n.s. – non-significant at 5% level by F test; significant at 5% (*), 1% (**) and 0.1% (***) by F test.

Table 2. Vine growth of 'Syrah' vines subjected to the application of municipal solid waste compost (MSWC) and cattle manure (Manure). A control (Ctrl) with no application of organic amendments was considered. Data are means of 36 vines from both experimental sites. The interaction between pruning and experimental site was never significant.

	Shoots vine^{-1}				Shoot weight (g)				Pruning weight (kg vine^{-1})			
Year	1	2	3	4	1	2	3	4	1	2	3	4
Ctrl	26	32	34	32	25	18 b	21	15	0.66	0.61 b	0.71 b	0.48
MSWC	27	34	37	36	26	21 ab	22	19	0.71	0.74 ab	0.84 ab	0.70
Manure	27	34	38	38	29	23 a	24	17	0.76	0.79 a	0.89 a	0.60
Sig.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s	n.s	n.s.	*	*	n.s.

Sig. – Significance level; n.s. – non-significant at 5% level by F test; significant at 5% (*), 1% (**) and 0.1% (***) by F test.

The dry matter production (Table 3) was increased by both organic amendments, showing an increase in vine capacity. On the other hand, Ravaz index (Table 3) was also increased by organic amendments, showing that the higher carbohydrate production was directed preferably to reproductive growth, instead of vegetative growth. Gaiotti et al. (2017), working with a cane pruned vineyard, found no variation of the Ravaz index with the application of cattle manure. However, in this case, the vineyard is mechanically pruned and vines with this type of pruning tend to favor reproductive growth and reserves formation instead of shoots development (Clingeleffer and Krake, 1992), leading to an increase in Ravaz index.

Table 3. Annual dry matter production of 'Syrah' vines subjected to the application of municipal solid waste compost (MSWC) and cattle manure (Manure). A control (Ctrl) with no application of organic amendments was considered. Data are means of 36 vines from both experimental sites. The interaction between pruning and experimental site was never significant.

	Dry matter production (t ha^{-1})				Ravaz index			
Year	1	2	3	4	1	2	3	4
CTRL	5.14	4.52 b	5.90 b	4.67 b	7.62	8.31	8.83 b	10.45 b
MSWC	5.6	5.49 a	7.99 a	7.18 a	8.01	7.99	11.39 a	11.18 ab
Manure	6.36	6.31 a	8.05 a	7.06 a	8.02	8.88	10.00 a	12.72 a
Sig.	n.s.	***	**	*	n.s.	n.s.	*	*

Sig. – Significance level; n.s. – non-significant at 5% level by F test; significant at 5% (*), 1% (**) and 0.1% (***) by F test.

According to Ramos (2017), working with young vineyards, the differences in yield, with the application of organic compost to soil, are more pronounced in dry years, due to the important role of soil organic matter in water hold capacity. In this experiment, the yield differences between treatments were similar in wet (year 3) and dry (year 4) years. However, in what concerns to dry matter production, the differences were more expressive in the year 4 (35%) than in year 3 (26%), meeting the tendency observed by Ramos (2017).

In years 2 and 3, grape composition was analyzed at harvest (Table 4). Data show that, with exception of PAC in the year 3, grape composition was not significantly affected by the application of organic amendments to soil. In the third year of the trial, PAC decreased with the application of MSWC and Manure, but, in this year, the production level was higher than in the second and, although the difference between treatments in year 2 (29% between Ctrl and Manure) has not been very different from year 3 (28% between Ctrl and the two organic amendments), in the last one the productivity of the organic amendments treatments raised until a level that, probably delayed ripening (Clingeleffer, 1988).

Table 4. Grape composition of 'Syrah' vines subjected to the application of municipal solid waste compost (MSWC) and cattle manure (Manure). A control (Ctrl) with no application of organic amendments was considered. Data are means of six 100-berries samples from both experimental sites. The interaction between pruning and experimental site was never significant.

	PAC (% vol.)		pH		Total acidity (g L^{-1})		Anthocyanins (mg L^{-1})		Total phenols	
Year	**2**	**3**	**2**	**3**	**2**	**3**	**2**	**3**	**2**	**3**
CTRL	13.9	12.6 a	3.46	3.38	5.25	5.48	1626	934	62	36
MSWC	13.4	11.9 b	3.44	3.45	5.19	5.70	1461	903	54	34
Manure	13.2	11.9 b	3.42	3.37	5.25	5.85	1407	946	50	37
Sig.	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Sig. – Significance level; n.s. – non-significant at 5% level by F test; significant at 5% (*), 1% (**) and 0.1% (***) by F test.

PAC – Probable alcoholic content.

CONCLUSIONS

The application of organic amendments to soil has enhanced productivity without reduction of vegetative growth. The dry matter production was higher and the carbohydrates gain was preferably directed to reproductive growth. Despite the increase in productivity, the grape composition in treatments with organic amendments was not different from Ctrl, except when yield exceeded a certain level and led to a delay in ripening. However, if the harvest date was delayed, the results would be probably different.

MSWC and Manure improved yield without significant quality loss, proving to be good options for increase vineyard profitability. Since cattle manure is becoming less available, MSWC seems to be a good option for increasing soil organic matter and fertilize vineyards. However, these organic amendments, usually, have variable levels of heavy metals which must be considered when deciding to use this option.

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