Effect of Organic Fertilizers on Soil Chemical Properties on Vineyard Calcareous Soil

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Summary

Organic fertilizers are an important contribution of organic matter that modify the physical, chemical and microbiological characteristics of the soil. The aim of investigation was to determine the effect of different organic fertilization on soil chemical properties on vineyard calcareous soil. Two-year fertilization trial was carried out in the Plešivica wine-growing region, in a 10-year old vineyard, cv. Sauvignon White grafted on Kobber 5BB rootstock, planted on soil with quite high pH for grapevine growing. The trial was performed according to randomize complete block design with 6 treatments (unfertilized, farmyard manure 20 t ha^{-1} and 40 t ha^{-1}, peat 20 000 L ha^{-1} and 40 000 L ha^{-1}, NPK 5-20-30 500 kg ha^{-1}+200 kg UREA ha^{-1}) in 4 repetitions.

Statistically significant differences in soil reaction (pH) in plowing layer (0-30 cm) were found among fertilization treatments in the second year of studies.

In the plowing layer (0-30 cm) in both years of the study significant differences between the values of average total nitrogen content and available phosphorus as well were found, while there were no significant differences in the subplowing layer (30-60 cm).

Regarding to average value of fertilization treatment, statistically significant difference in the content of available potassium in plowing layer were found in the both investigated years, while in subplowing layer statistical differences were found in the first year of investigation only. Therefore, fertilization with different organic fertilizers significantly influenced the most of studied chemical properties of the soil, especially in plowing layer (0-30 cm).

Key words

chemical properties, farmyard manure, organic matter, peat, vineyard

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Introduction

Soils of the Plešivica vine-growing region (Croatia) are of heavy mechanical composition, low air capacity, and high CaO content; all this favours formation of HCO_3^{2-} ions, which cause disturbances in the uptake of biogenic elements and different types of chlorosis (Petek et al., 2008). Furthermore, the most common rootstocks in that sub-region are SO4 and Kober BB which are very sensitive to the increased amount of the total and active lime which leads to occurrence of chlorosis and necrosis on the vine due to reduced supply of biogenic elements (Herak Ćustić et al., 2009).

According to Herencia et al. (2008), application of organic materials influences on the distribution of biogenic elements as well as better accessibility of microelements to plants.

Furthermore, the use of organic fertilizers is associated with the desired characteristics of the soil, including a greater capacity for water, cation exchange capacity, and lower soil bulk density. Also, organic matter stimulate growth and development of beneficial microorganisms (Doran, 1995; Bulluck et al., 2002 according to Kaur et al., 2005).

Addition of organic matter to soil may result in increases or decreases in soil pH, depending on the influence which the addition has on the balance of the various processes which consume and release protons (Baldock and Nelson, 2000).

The complexation of inorganic cations by soil organic materials can increase availability of insoluble mineral P through complexation of Fe^{3+} and Al^{3+} in acid soil and Ca^{2+} in calcareous soil, competition for P adsorption sites, and displacement of adsorbed P (Stevenson, 1994; Cajuste et al., 1996, according to Baldock and Nelson, 2000). Also, Kaur et al. (2005) allegation that application of farmyard manure or polutry manure improved the soil organic C, total N, P and K status. Futhermore, application of manure resulted in an increase in soil mineral content as compared to control treatment and in general the elements such as N, P, K, Fe, Zn, Mn, Cu, Cd and Pb in the soil, were increased by increasing the rate of manure, also organic matter was improved by manure application, while soil pH was lowered (Abebe, 2001 according to Abu-Zahra and Tahboub (2008).

Comparing the 14 long-term (20-120 years) fertilization trials (mineral fertilizers and organic fertilizers: manure, slurry and green manure) Edmeades (2003) concludes that there is no consistent impact of organic fertilizers on the change of pH in the soil. However, the application of organic fertilizers leads to enrichment of the plowing layer with phosphorus and potassium, and sometimes calcium and magnesium, but the same author warns that the long term application of organic fertilizers in relation to the mineral fertilizers may cause excessive enrichment of the soil with some nutrients, especially phosphorus, potassium, calcium and magnesium in the plowing layer, and nitrate nitrogen, calcium and magnesium in the subplowing layer.

On the other hand, after 34 years of application of different fertilizers (green manure, cereal straw, manure 35 and 70 t ha^{-1} every three years and slurry 60 m^3 ha^{-1} every three years, and four doses of mineral nitrogen) Maltas et al. (2012) concluded that organic fertilizers had no significant impact on major chemical properties of the soil, exept on the content of trace elements.

The aim of this investigation was to determine the effect of different organic fertilization on soil chemical properties on vineyard calcareous soil.

Materials and methods

The fertilization trial was set up on Plešivica wine-growing region, Borička location (northwestern Croatia), in a 10-year old vineyard, on grapevine (*Vitis vinifera* L.) cv. Sauvignon White grafted on Kobber 5BB rootstock, planted on soil with quite high pH for grapevine growing (pH_{H2O} 8.02), containing 2.81 mg P_2O_5 100 g^{-1} soil, 13.53 mg K_2O 100 g^{-1} soil and 13.5 % CaO. The two-year trial was set up according to randomize complete block design with 6 treatments (unfertilized, farmyard manure 20 t ha^{-1} and 40 t ha^{-1}, peat 20 000 L ha^{-1} and 40 000 L ha^{-1}, NPK 5-20-30 500 kg ha^{-1}+2x100 kg UREA ha^{-1}) in 4 repetitions. Soil chemical properties were determined in layers at 0-30 and 30-60 cm depths at the end of each growing season (October). The monitored soil chemical properties were: soil pH, organic matter, total nitrogen content, plant available phosphorus (P) and plant available potassium (K). Soil reaction was determined electrometrically by using combined electrode in a suspension of soil and water in a ratio of 1:2.5 (active acidity) (HRN ISO 10390:2004). Organic matter was determined by determination of organic carbon (HRN ISO 14235:1998). Total soil nitrogen was determined by the Kjeldahl method (AOAC, 1995). Plant available phosphorus and potassium were determined by ammonium-lactate extraction (Egner et al., 1960). Phosphorus was determined by using a spectrophotometer and potassium by using a flame-photometer. Statistical data analyses were performed using the SAS 8.2 System (2002-2003).

Results

Soil reaction (pH)

Average values of the pH_{KCl} at two depts (0-30 and 30-60 cm) at the end of the growing season are presented in Tables 1 and 2.

Considering the average value of fertilization treatments, statistically significant differences were found in the second year of investigation in plowing layer (0-30 cm).

Fertilization treatment with acidic peat (40 000 L ha^{-1}) significantly affected the reduction of the soil pH value (7.14), while the highest value was recorded on treatment with 40 t ha^{-1} manure (7.23).

According to the two-year average values of the fertilization treatments, the lowest pH value (7.19) in plowing layer (0-30 cm) was determined in fertilization treatment with 20 000 L ha^{-1} and 40 000 L ha^{-1} acidic peat, while significantly highest pH values were recorded at fertilization with 20 and 40 t ha^{-1} manure (7.25 and 7.26, respectively).

In subplowing layer influence of fertilization treatments was lower, so there were no significant differences between determined pH values by years (Table 2).

Organic matter

Average values of the content of organic matter in the soil at the end of the growing season (harvest) are shown in Tables 3 and 4.

Table 1. Soil reaction (pH) according to fertilization treatments and years of research at depth of 0-30 cm

Fertilization treatments	pH_{KCl} (0-30 cm)		
	1st year	2nd year	Average
Unfertilized	7.28 a	7.18 ab	7.22 ab
Manure 20 t ha^{-1}	7.32 a	7.18 ab	7.25 a
Manure 40 t ha^{-1}	7.30 a	7.23 a	7.26 a
Peat 20 000 L ha^{-1}	7.22 a	7.17 ab	7.19 b
Peat 40 000 L ha^{-1}	7.25 a	7.14 b	7.19 b
500 kg ha^{-1} NPK 5-20-30 +200 kg ha^{-1}UREA	7.26 a	7.18 ab	7.22 ab

Means accompanied by different letters in the same year of sampling are significantly different according to Tukey's HSD test ($P \leq 0.05$).

Table 2. Soil reaction (pH) according to fertilization treatments and years of research at depth of 30-60 cm

Fertilization treatments	pH_{KCl} (30-60 cm)		
	1st year	2nd year	Average
Unfertilized	7.24 a	7.19 a	7.21 b
Manure 20 t ha^{-1}	7.29 a	7.19 a	7.24 ab
Manure 40 t ha^{-1}	7.32 a	7.23 a	7.27 a
Peat 20 000 L ha^{-1}	7.22 a	7.18 a	7.20 b
Peat 40 000 L ha^{-1}	7.23 a	7.16 a	7.19 b
500 kg ha^{-1} NPK 5-20-30 +200 kg ha^{-1}UREA	7.22 a	7.19 a	7.21 b

Means accompanied by different letters in the same year of sampling are significantly different according to Tukey's HSD test ($P \leq 0.05$).

Table 3. Content of organic matter according to treatments and years of research at depth of 0-30 cm

Fertilization treatments	% organic matter(0-30 cm)		
	1st year	2nd year	Average
Unfertilized	2.33 a	2.17 a	2.25 a
Manure 20 t ha^{-1}	2.17 a	2.41 a	2.29 a
Manure 40 t ha^{-1}	2.99 a	1.98 a	2.48 a
Peat 20 000 L ha^{-1}	2.63 a	2.12 a	2.38 a
Peat 40 000 L ha^{-1}	2.87 a	1.73 a	2.30 a
500 kg ha^{-1} NPK 5-20-30 +200 kg ha^{-1}UREA	2.32 a	2.04 a	2.18 a

Means accompanied by different letters in the same year of sampling are significantly different according to Tukey's HSD test ($P \leq 0.05$).

Table 4. Content of organic matter according to fertilization treatments and years of research at depth of 30-60 cm

Fertilization treatments	% organic matter (30-60 cm)		
	1st year	2nd year	Average
Unfertilized	1.91 a	1.85 a	1.88 a
Manure 20 t ha^{-1}	1.76 a	1.96 a	1.86 a
Manure 40 t ha^{-1}	2.46 a	1.70 a	2.08 a
Peat 20 000 L ha^{-1}	1.97 a	1.90 a	1.94 a
Peat 40 000 L ha^{-1}	2.18 a	1.48 a	1.83 a
500 kg ha^{-1} NPK 5-20-30 +200 kg ha^{-1}UREA	1.77 a	2.07 a	1.92 a

Means accompanied by different letters in the same year of sampling are significantly different according to Tukey's HSD test ($P \leq 0.05$).

In both years of research there were no significant differences between average values of the content of organic matter.

However, in two-year average values, the relatively highest content of organic matter was recorded at fertilization with 40 t ha^{-1} manure (2.48% at a depth of 0-30 cm and 2.08% at a depth of 30-60 cm). On the other side, the relatively lowest value of content of organic matter were recorded at fertilization with 500 kg ha^{-1} NPK 5-20-30 + 200 kg ha^{-1} UREA (2.18%) in plowing layer, and at fertilization with 40 000 L ha $^{-1}$ acidic peat in subplowing layer (1.83%).

Nitrogen

Average values of total nitrogen (% N) in the soil at the end of the growing season (harvest) are presented in Tables 5 and 6.

In the plowing layer (0-30 cm) in both years of the study there were significant differences between the average content of total nitrogen, while in subplowing layer (30-60 cm) were no statistically significant differences. After the first growing season, the highest content of total nitrogen (0.21%) was recorded at fertilization with 500 kg ha^{-1} NPK 5-20-30 + 200 kg ha^{-1} UREA, while in second year, the highest content of determined total nitrogen values were recorded at three fertilization treatments: 40 t ha^{-1} manure (0.19% N), 40 000 L ha^{-1} acidic peat (0.19% N), and 500 kg ha^{-1} NPK 5-20-30 + 200 kg ha^{-1} UREA (0.18% N).

In both years of research the lowest content of total nitrogen were determined in the control treatment (0.15 and 0.13% N, respectively) and treatment with 20 t ha^{-1} manure (0.15 and 0.14% N, respectively).

Table 5. Content of total nitrogen (% N) according to fertilization treatments and years of research at depth of 0-30 cm

Fertilization treatments	% N (0-30 cm)		
	1st year	2nd year	Average
Unfertilized	0.15 c	0.13 b	0.14 c
Manure 20 t ha^{-1}	0.15 c	0.14 b	0.15 c
Manure 40 t ha^{-1}	0.20 ab	0.19 a	0.19 a
Peat 20 000 L ha^{-1}	0.17 bc	0.16 ab	0.17 b
Peat 40 000 L ha^{-1}	0.20 ab	0.19 a	0.19 a
500 kg ha^{-1} NPK 5-20-30 +200 kg ha^{-1}UREA	0.21 a	0.18 a	0.19 a

Means accompanied by different letters in the same year of sampling are significantly different according to Tukey's HSD test ($P \leq 0.05$).

Table 6. Content of total nitrogen (% N) according to fertilization treatments and years of research at depth of 30-60 cm

Fertilization treatments	% N (30-60 cm)		
	1st year	2nd year	Average
Unfertilized	0.14 a	0.14 a	0.14 c
Manure 20 t ha^{-1}	0.16 a	0.15 a	0.16 ab
Manure 40 t ha^{-1}	0.18 a	0.16 a	0.17 a
Peat 20 000 L ha^{-1}	0.15 a	0.14 a	0.14 bc
Peat 40 000 L ha^{-1}	0.16 a	0.16 a	0.16 ab
500 kg ha^{-1} NPK 5-20-30 +200 kg ha^{-1}UREA	0.15 a	0.13 a	0.14 bc

Means accompanied by different letters in the same year of sampling are significantly different according to Tukey's HSD test ($P \leq 0.05$).

Table 7. Content of available phosphorus (mg P_2O_5 100 g^{-1} soil) according to fertilization treatments and years of research at depth of 0-30 cm

Fertilization treatments	mg P_2O_5 100 g^{-1} (0-30 cm)		
	1st year	2nd year	Average
Unfertilized	2.81 c	2.44 b	2.62 c
Manure 20 t ha^{-1}	7.01 b	4.34 ab	5.68 bc
Manure 40 t ha^{-1}	13.13 a	6.01 a	9.57 a
Peat 20 000 L ha^{-1}	9.89 b	3.99 ab	6.94 b
Peat 40 000 L ha^{-1}	10.14 b	3.31 ab	6.73 b
500 kg ha^{-1} NPK 5-20-30 +200 kg ha^{-1}UREA	9.14 b	4.05 ab	6.60 b

Means accompanied by different letters in the same year of sampling are significantly different according to Tukey's HSD test ($P \le 0.05$).

Table 8. Content of available phosphorus (mg P_2O_5 100 g^{-1} soil) according to fertilization treatments and years of research at depth of 30-60 cm

Fertilization treatments	mg P_2O_5 100 g^{-1} (30-60 cm)		
	1st year	2nd year	average
Unfertilized	3.86 a	3.01 a	3.43 b
Manure 20 t ha^{-1}	4.58 a	3.56 a	4.07 b
Manure 40 t ha^{-1}	7.38 a	4.93 a	6.15 a
Peat 20 000 L ha^{-1}	5.43 a	3.34 a	4.38 ab
Peat 40 000 L ha^{-1}	6.13 a	2.88 a	4.51 ab
500 kg ha^{-1} NPK 5-20-30 +200 kg ha^{-1}UREA	5.29 a	2.33 a	3.81 b

Means accompanied by different letters in the same year of sampling are significantly different according to Tukey's HSD test ($P \le 0.05$).

Table 9. Content of available potassium (mg K_2O 100 g^{-1} soil) according to fertilization treatments and years of research at depth of 0-30 cm

Fertilization treatments	mg K_2O 100 g^{-1} (0-30 cm)		
	1st year	2nd year	Average
Unfertilized	13.53 b	14.25 a	13.89 c
Manure 20 t ha^{-1}	30.38 a	14.50 a	22.44 b
Manure 40 t ha^{-1}	33.38 a	19.45 a	26.41 ab
Peat 20 000 L ha^{-1}	32.75 a	16.05 a	24.40 ab
Peat 40 000 L ha^{-1}	33.00 a	18.68 a	25.84 ab
500 kg ha^{-1} NPK 5-20-30 +200 kg ha^{-1}UREA	38.63 a	17.45 a	28.04 a

Means accompanied by different letters in the same year of sampling are significantly different according to Tukey's HSD test ($P \le 0.05$).

Table 10. Content of available potassium (mg K_2O 100 g^{-1} soil) according to fertilization treatments and years of research at depth of 30-60 cm

Fertilization treatments	mg K_2O 100 g^{-1} (30-60 cm)		
	1st year	2nd year	Average
Unfertilized	14.80 a	14.33 ab	14.56 c
Manure 20 t ha^{-1}	25.55 a	12.73 b	19.14 b
Manure 40 t ha^{-1}	28.88 a	16.30 ab	22.59 ab
Peat 20 000 L ha^{-1}	26.13 a	14.95 ab	20.54 ab
Peat 40 000 L ha^{-1}	28.75 a	17.73 a	23.24 a
500 kg ha^{-1} NPK 5-20-30 +200 kg ha^{-1}UREA	28.00 a	15.70 ab	21.85 ab

Means accompanied by different letters in the same year of sampling are significantly different according to Tukey's HSD test ($P \le 0.05$).

Phosphorus

Average values of available phosphorus at two depths (0-30 and 30-60 cm) at the end of the growing season (harvest) are shown in Tables 7 and 8.

In the plowing layer (0-30 cm) in both years of the study there were significant differences between the average content of available phosphorus, while in subplowing layer (30-60 cm) were no statistically significant differences.

According to the average values of individual treatments in both years of investigation statistically the higest content of available phosphorus were observed in fertilization with 40 t ha^{-1} manure (13.13 and 6.01 mg P_2O_5 100 g^{-1}, respectively), while the lowest content of available phosphorus was observed in the control treatment (2.81 and 2.44 mg P_2O_5 100 g^{-1}, respectively).

According to the two-year average values of the individual treatments the highest content of available phosphorus in both investigated depths were found at fertilization with 40 t ha^{-1} manure (9.57 and 6.15 mg P_2O_5 100 g^{-1}, respectively). Significantly the lowest content of available phosphorus in the plowing layer was observed at the control treatment (2.62 mg P_2O_5 100 g^{-1}).

Potassium

Average values of available potassium at two depths (0-30 and 30-60 cm) at the end of the growing season (harvest) are shown in Tables 9 and 10.

Considering the average values of fertilization treatment, statistically significant differences in plowing layer was found in the first, while in subplowing layer statistically significant differences were found in the second year of study.

In plowing layer, significantly the highest content of available potassium in the first year of research were found in all treatments of fertilization: 500 kg ha^{-1} NPK 5-20-30 + 200 kg ha^{-1} UREA (38.63 mg K_2O 100 g^{-1}) 40 t ha^{-1} manure (33.38 mg K_2O 100 g^{-1}), 40 000 L ha^{-1} acidic peat (33.00 mg K_2O 100 g^{-1} soil), and 20 000 L ha^{-1} acidic peat (32.75 mg K_2O 100 g^{-1}) and 20 t ha^{-1} manure (30.38 mg K_2O 100 g^{-1}) in relation to the control treatment (13.53 mg K_2O 100 g^{-1}).

In the second year of study, in subplowing layer statistically the highest content of available potassium was observed in fertilization with 40 000 L ha^{-1} acidic peat (17.73 mg K_2O 100 g^{-1}), and the lowest content at fertilization with 20 t ha^{-1} manure (12.73 mg K_2O 100 g^{-1}).

According to the two-year average values of certain treatments significantly the highest content of available potassium in plowing layer was observed at fertilization with 500 kg ha^{-1} NPK 5-20-30 + 200 kg ha^{-1} UREA (28.04 mg K_2O 100 g^{-1}), while in subplowing layer this value was the highest at fertilization with 40 000 L ha^{-1} acidic peat (23.24 mg K_2O 100 g^{-1}). Statistically significant the lowest content in both investigated depths was recorded at control treatment (13.89 and 14.56 mg K_2O 100 g^{-1}, respectively).

Discussion

According to results of this research, depending on the year and depth, organic fertilizers were significantly affected the soil reaction, nitrogen, and physiologically active phosphorus and potassium.

Decrease of soil reaction in plowing layer (0-30 cm) was mostly influenced by the application of acidic peat (pH_{KCl} = 7.19) regardless of the applied dose (20 t ha^{-1} and 40 t ha^{-1}). However, the application of manure (20 t ha^{-1} and 40 t ha^{-1}) resulted in an increase of soil reaction in both examined depth (pH_{KCl} = 7.25; pH_{KCl} = 7.26), which is in accordance to Petek (2008), although Edmeades (2003) concluded that there is no consistent or significant influence of organic fertilizer to the change of pH in the soil.

Average content of total nitrogen in plowing layer was in the range 0.14 to 0.19% N, and in subplowing layer from 0.14 to 0.17% N. Increasing of the content of total nitrogen in plowing layer was equally influenced by three fertilization treatments (40 t ha^{-1} manure, 40,000 L ha^{-1} acidic peat, and fertilization with 500 kg ha^{-1} NPK 5-20-30 + 200 kg ha^{-1} UREA), which was expected considering the content of nitrogen in these fertilizers, and it's in accordance with Mao et al. (2008). This effect in subplowing layer was kept only by treatment with 40 t ha^{-1} manure.

An average content of available phosphorus in plowing layer varied in the range from 2.62 to 9.57 mg P_2O_5 100 g^{-1} soil, and in subplowing layer from 3.43 to 6.15 mg P_2O_5 100 g^{-1} soil. The highest content of available phosphorus in both investigated depths were determined at fertilization with 40 t ha^{-1} manure (9.57, and 6.15 mg P_2O_5 100 g^{-1} soil). That could be compared with the results of Courtney and Mullen (2008), while Kaur et al. (2005) recorded the highest amount of available phosphorus at fertilization with combination of organic and mineral fertilizers.

Average amounts of available potassium in plowing layer varied in the range from 13.89 to 28.04 mg K_2O 100 g^{-1} soil, and in subplowing layer from 14.56 to 23.24 mg K_2O 100 g^{-1} soil. The higest content of available potassium in the plowing layer was observed at fertilization with 500 kg ha^{-1} NPK 5-20-30 + 200 kg ha^{-1} UREA, which was expected due to the content of potassium in the mentioned mineral fertilizer.

Conclusions

Decrease of soil pH, according to the average annual values of treatment, in plowing layer (0-30 cm) was determined at fertilization with 20 000 or 40 000 L ha^{-1} acidic peat, whereas a significant increase in pH was recorded with the fertilization 20 t ha^{-1} and 40 t ha^{-1} (pH 7.26) of manure.

Fertilization relatively increased the content of organic matter. In both examined depths relatively highest content of organic matter was determined at fertilization with 40 t ha^{-1} manure.

Significant increase of total nitrogen in plowing layer was affected by three fertilization treatments, while in subplowing layer, the highest content of total nitrogen was recorded at fertilization with 40 t ha^{-1} manure.

The highest content of available phosphorus in both investigated depths were determined at fertilization with 40 t ha^{-1} manure.

In the first year all treatments of fertilization significantly raised level of available potassium, while this effect in the second year, as well as in subplowing layer was weaker.

Therefore, fertilizing with different organic fertilizers significantly influenced the most of studied chemical properties of the soil, especially in plowing layer (0-30 cm).

According to this study, the most positive effects was found by applying of higher doses of farmyard manure. However, farmyard manure causes an increase in the pH value which is undesirable in calcareous soils. Therefore, combination of farmyard manure and acidic peat should be investigate in order to avoid this undesirable effect.

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