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Strawberry (*Fragaria* × *ananassa* Duch.) yield as affected by the soil pH

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ABSTRACT

Two-year trials (2006-2007) suggested that the use of calcium oxide (CaO) on acid soils increased soil pH and yiel in strawberry cultivars Marmolada, Selena and Senga Sengana, under the environmental conditions of Cacak (Weste Serbia). The highest yield was obtained when CaO was applied at 750 kg ha^{-1} rate. Further increase in rate up 1,500 kg ha^{-1} did not show corresponding increase in yield; the result was a slight yield drop compared to the pe yield shown at 750 kg ha^{-1} rate. Overall, yields at rates above 750 kg ha^{1} were still higher than control and in t treatment employing lowest CaO application rate of 250 kg ha^{-1}.

Key words: acid soils, CaO, pH, strawberry, yield.

INTRODUCTION

In Republic of Serbia, strawberries are being cultivated on soils with pH ranging between 4 and 8. Milosevic (1997) shows that acid soils with pH 4.0 are less suitable for strawberry production than alkaline soils with pH 8.0. In these extreme soil pH values strawberry production, yield potential and fruit quality are seriously compromised. According to Milosevic (1997) optimum soil pH for strawberry cultivation ranges from 4.6–6.5. A highly marked increase in substitutional acidity is being exhibited in 22% of soils in Serbia, and 56% of soils have pH values consistent with acid reaction. As reported by Cakmak (2002), 60% of world soils exert limiting effects on food production due to their degradation, micronutrient deficiencies and toxicity traits.

The subject matter of this study is strawberry cultivation on acid soils subjected to treatments aimed at

plications to the soil. A great number of authors et al. 1999, Burelle 2003) have studied the ef soil as a primary substrate on vegetative growth, ductive cycle, strawberry yield, accumulation of elements, particularly heavy metals (Cd), in the leaves and fruits.

The objective of the study was to determ most favourable CaO rate that would bring soil the level that would insure highest possible yie unit area.

Several authors (Makus and Morris 1989, et al. 1990, 1991, Na Phun et al. 1995, 1997, and Lewandowski 2003, Lanauskas et al. 2006) h ported seeing positive effects of soil and/or foliar- calcium-containing compounds on yield and fru ity in strawberries as well as on soil pH increase (1999, Lacertosa et al. 1999, Niskanen and Dris Cieslinski et al. (2004) showed that increased s

MATERIALS AND METHODS

Trials were conducted in 2006 and 2007 in a strawberry planting at Prislonica situated 15 km north-east of Cacak (43°53′N; 20°21′E), Western Serbia at an altitude of 530 m. The research material included most commonly grown strawberry cultivars Marmolada, Selena and Senga Sengana. The cultivars were grown as "frigo" seedlings planted at the beginning of August in 2005 and in 2006 in simple rows at 80 × 25 cm spacing (50,000 seedlings per hectare). The flowers were cut back in autumn.

The trial was set up as a randomised block design in four replications for a single treatment, with each replication including a control. The experimental plot was 10 m^2. Adjoining plots were separated with 1 m wide insulating tape.

In October of 2005 and 2006 CaO was broadcasted by hand immediately incorporated into the soil. CaO treatments were as follows:

$A_1 = 0$ (control),
$A_2 = 250$,
$A_3 = 500$,
$A_4 = 750$,
$A_5 = 1,000$,
$A_6 = 1,250$ and
$A_7 = 1,500$ kg ha^{-1}.

In March of 2006 and 2007, 500 kg of NPK (10:12:26), and 150 kg lime ammonium nitrate (27%) per hectare were incorporated into the soil. Provided plant care was in accordance with the modern strawberry production technology. Soil analysis was done prior to strawberry planting and after the harvest. A Pye glass electrode pH-meter-potentiometer (W.G. Pye, Cambridge) was used to measure the pH value in 0.01 M KCl.

Experimental data were subjected to analysis of variance. For mean separation a Dunett's test at $P < 0.05$ and $P < 0.01$ was used. The data were analyzed by the ANOVA statistical program, Origin, version 7.5. Correlation and regression analysis and analysis of the variance of regression at $P < 0.05$ and $P < 0.01$

WEATHER AND SOIL CHARACTERISTICS

Climate conditions during the examination were not significantly different from the long-term averages. In 2006, the average annual temperature was 9.1°C, and the average temperature for the growing season was 15.3°C. The total annual and total growing season precipitations were 561.9 mm m^{-2} and 343.9 mm m^{-2}, respectively. In 2007, the average annual temperature was 11.6° and the average temperature for the growing season was 18.0°C. The total annual and growing-season rainfalls were 505.4 mm m^{-2} and 205.0 mm m^{-2}, respectively.

The planting was established on brown forest soil developed from schist. Prior to establishing the trial planting and calcium-oxide treatments, soil was showing a highly acid reaction (pH 4.12). Soil analysis reviled following nutrient levels: 2.14% humus, 0.14% total nitrogen, 50 mg kg^{-1} P_2O_5 and 110 mg kg^{-1} K_2O at a depth of 0–40 cm.

RESULTS

Our results indicate that the soil acidity (pH) is affected by the CaO application rate as shown in Table I.

The data analysis showed that high CaO application rates resulted in decreasing soil acidity showing higher pH values as expressed in absolute and relative amounts. The maximum CaO application rate of 1,500 kg ha^{-1} raised pH readings for 2.10-unit or 33.76% compared to the control. This is also confirmed by the linear regression curve (Fig. 1) with a shape $Y = 3.85 + 0.37x$ and a very high correlation ($r = 0.959$) coefficient. The regression variance analysis detected statistically significant differences between the soil pH obtained by increasing CaO rates and the control ($P < 0.05$).

The trial results presented in Table II and Figure 2 show that the use of CaO for raising the soil pH had positive effect on strawberry yields. The yields obtained in all the treatments were higher than those in the control. The highest yield in all cultivars examined was obtained in the trial plot where 750 kg ha^{-1} CaO (A_4) was applied. At this rate there was an increase in pH

TABLE I
CaO treatments (kg ha^{-1}) and changes in the soil pH.

Treatment	CaO rate (kg ha^{-1})						
	0 (Control)	250	500	750	1,000	1,250	1,500
pH value	4.12	4.57	4.74	5.75	5.93	6.04	6.22
The pH difference as compared to the initial value (4.12)							
Absolute	—	0.45	0.62	1.63	1.81	1.92	2.10
Relative (%)	—	9.85	13.08	28.35	30.52	31.79	33.76

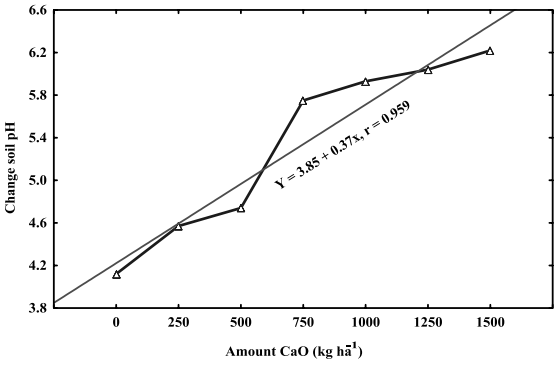


Fig. 1 – CaO rates and pH trends.

in Marmolada, 9.65 t ha^{-1} in Selena and 8.50 t ha^{-1} in Senga Sengana cultivars. With the highest-yielding A_4 treatment, the yield varied from 19.70 t ha^{-1} (Senga Sengana), 21.75 t ha^{-1} (Selena), and 23.12 t ha^{-1} (Marmolada). Compared to control the highest yield increase was recorded in Senga Sengana (131.76%), followed by Selena (125.36% and Marmolada (118.11%).

The analysis of variance and the Dunett's test showed statistically significant ($P < 0.01$) increase in maximum yields compared to control with the CaO application rate of 750 kg ha^{-1}.

DISCUSSION

This study supports data cited in literature (Milosevic 1997, Niskanen and Dris 2002) that the most favourable pH for t strawberry production is between 4.6 and 6.5. Similar data were reported by Cieslinski et al. (2004) who determined that pH 5.1 and pH 6.8 had different effects on plant development and strawberry yield – better

Further CaO application rate increase exc
750 kg ha^{-1} resulted in a gradual yield decreas
observation can serve as an important indicator in
berry production on acid soils. Importantly, th
evidently decreased with respect to the 750 kg ha
application rate (A_4) but increased as compared
control (A_1) and the lowest rate treatment (250 k
CaO). Lanauskas et al. (2006) determined that
ha^{-1} $Ca(NO_3)_2$ applied to the soil were not su
to justifiably increase the yield and fruit weight
Honeoye strawberry cultivar as compared to th
trol (without fertilisation) on the soil with the pH
According to Brocic (1997) 4,000 kg ha^{-1} CaO
quired to decrease acidity by 0.7 pH units on pseu
being eight times the rates applied in this study
caused similar changes in pH. The differences ar
to be due to soil types, as the soil in our study is
forest soil developed from schist, that is far more
and richer in organic and mineral matter than p
gley soil. The climatic conditions in the researc
were nearly identical thus they could not have ma
affected studied parameters.

Strawberry cultivars in all treatments re
identical nutritional regime involving the applicat
NPK (10:12:26) at the rate of 500 kg ha^{-1}, and 150
lime ammonium nitrate therefore nutrient manag
was not responsible for the yield increases. Th
increase as induced by the use of different CaO r
acid soils may be attributed to the effect of soil p
Ca^{2+} ions on the mobilisation and uptake of certa
from the soil by the strawberry root system.

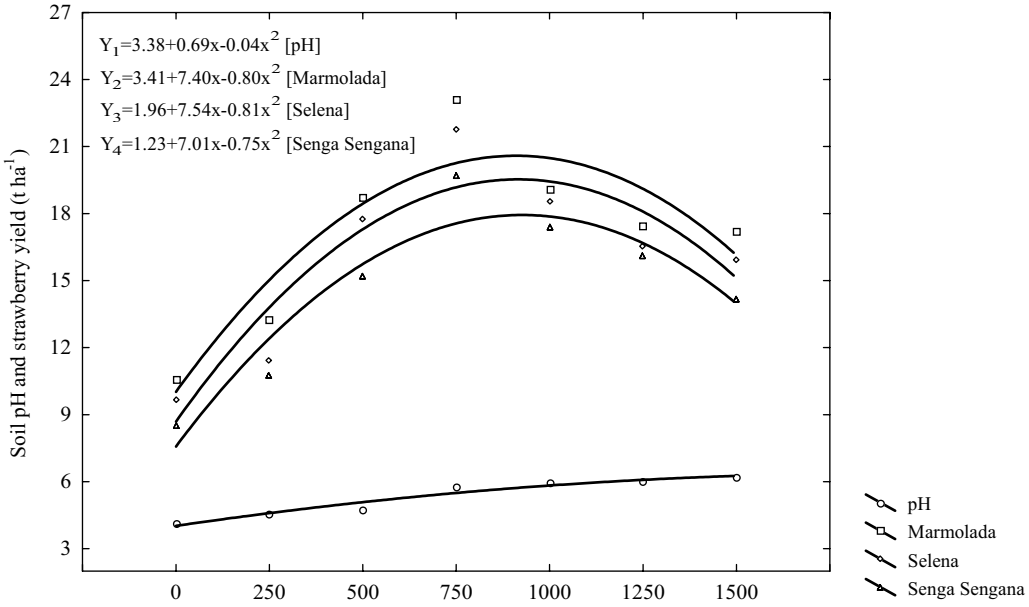
TABLE II
Strawberry yield dynamics as affected by changes in pH.

Cultivars	pH value						
	4.12	4.57	4.74	5.75	5.93	6.04	6.22
	Yield (t ha^{-1})						
Marmolada	10.60	13.25	18.75	23.12	19.10	17.45	17.20
Selena	9.65	11.40	17.75	21.75	18.55	16.55	15.95
Senga Sengana	8.50	10.75	15.20	19.70	17.40	16.10	14.15
Average yield (t ha^{-1})	9.58	11.80	17.23	21.52	18.35	16.70	15.77
Average yield difference as compared to the initial yield at pH = 4.12							
Absolute (t ha^{-1})	–	2.22	7.65	11.94	8.77	7.12	6.19
Relative (%)	–	23.17	79.85	124.63	91.54	74.32	64.61

TABLE III
Yield of strawberry cultivars obtained in the control (A_1) without CaO application and in the A_4 treatment with 750 kg ha^{-1} CaO which resulted in the highest yield.

Cultivars		Yield (t ha^{-1})		Yield increase compared to control (%)
		A_1 (Control) (0 kg ha^{-1} CaO)	A_4 (750 kg ha^{-1} CaO)	
Marmolada		10.60	23.12**	118.11
Selena		9.65	21.75**	125.39
Senga Sengana		8.50	19.70**	131.76
d′	$P < 0.05$	1.512		—
	$P < 0.01$	2.106		

The asterisks indicate a significant difference between means at $P < 0.01^{(**)}$ level.



berry yield may suggest the following conclusions: the use of CaO on acid soil increased soil pH and yield increases in Marmolada, Selena and Senga Sengana strawberry cultivars in all treatments applied. The highest yield was recorded with the 750 kg ha^{-1}CaO application rate, with pH of 5.75. The increase in CaO rates above 750 kg ha^{-1} did not bring corresponding increase in strawberry yield while showing slight decreasing tendency with respect to the rate mentioned. Overall at CaO rates above 750 kg ha^{-1} yield was higher than in the control (0 kg ha^{-1}) and the treatment employing the lowest application rate (250 kg ha^{-1}).

RESUMO

Dois anos de ensaios (2006-2007) sugeriram que o uso de óxido cálcio (CaO) em solos ácidos aumentou o pH do solo e o rendimento das cultivares de morango, Marmolada, Selena e Senga Sengana, sob as condições ambientais de Cacak (oeste da Sérvia). O rendimento mais elevado foi obtido quando CaO foi aplicado na quantidade de 750 kg ha^{-1}. O aumento da quantidade para nível até 1500 kg ha^{-1} não mostrou aumento correspondente do rendimento; o resultado foi uma ligeira queda em comparação com o rendimento máximo obtido a 750 kg ha^{-1}. Globalmente, os resultados a taxas superiores a 750 kg ha^{1} foram ainda mais elevados do que no controle e no tratamento empregando quantidade mais baixa de 250 kg ha^{-1} de CaO.

Palavras-chave: solos ácidos, CaO, pH, morango, produtividade.

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