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RELATIONSHIPS BETWEEN PARAMETERS OF SOIL AND CHARD (*BETA VULGARIS* L. VAR. *CICLA* L.)

SUMMARY

The results of investigation of relationship between agrochemical parameters of soil – pH, total carbonates, organic matter, available fraction of K, P, Ca, Mg, Fe, Mn, Zn and Cu – and nutrients in chard (*Beta vulgaris* L. var. *cicla* L.) are shown in this paper. The plants of chard were grown on neutral and alkaline soil with different agrochemical characteristics. The quality and quantity of chard depended on soil properties. The content of P, K and Mn in chard depended on its concentration in soil and the chard Ca and Mg were regulated by the content of exchangeable soil Ca and Mg. The opposite trend was noticed between soil pH and chard Mn and Cu content. The yield was in positive significant relationship with available soil.

Keywords: soil, chard, nutrient, relationship

INTRODUCTION

Swiss chard (*Beta vulgaris* L. var. *cicla* L.) is a leafy vegetable highly appreciated in many parts of the world for its nutritional properties, year round availability, low cost and wide use in many traditional dishes. The consumers favor Swiss chard for its lower price, while growers prefer it because it is more robust and easier to grow than spinach and celery (Miceli and Miceli, 2014). This vegetable is very low in saturated fat and cholesterol and is a good source of thiamin, folate, phosphorus and zinc, and a very good source of dietary fiber, vitamins A, C, E, K, B2, B6, calcium, iron, magnesium, potassium, copper and manganese. The bad is that chard is very high in sodium. The chard serving of 175 g contains 214%, 716%, and 53% of the recommended daily value of vitamins A, K, and C, respectively (Nutritiondata.self.com. Retrieved 2013-04-15).

The chard have been used for a long time for their beneficial health effects, mainly consisting in stimulation of haematopoietic and immune systems as well as in the protection of kidney, liver and gut from toxic compounds. Modern pharmacologists also addressed the importance of bioactive molecules from chard extracts and demonstrated their anti-diabetic, anti-inflammatory, antioxidant and anticancer activities (Ninfali and Angelino, 2013).

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However, chemical composition as well as nutritional value of chard may greatly vary depending on climatic conditions, soil characteristics and nutrient supply as important determinants of quantity and quality of yield of agricultural plants (Britto *et al.*, 2012). Swiss chard is a very nutritive demanding species. The content of mineral elements, total quality and yield are

influenced by the amount, frequency and method of fertilization (Miceli and Miceli C, 2014). Soil characteristics influence nutrient solubility, but also microbial activity and root growth (Knežević *et al*., 2009).

The aim of study was to characterize agrochemical condition of growing the chard and to correlate the results of soil and leaf analysis. In order to avoid shortcomings in the interpretation of simple relationship between nutrients in plant and soil parameters, the principal component analysis was applied.

MATERIAL AND METHODS

Chard Cultivation

Plants of chard were grown in the experimental field in Bjelopavlićka Plain, site Sige. The main soil characteristics and potential for plant production was mentioned in study of Knežević (2008). Seeds of chard (“Verca F1 hybrid”, producer – Clause, France) were sown in expanded polystyrene trays with cells supplied with peat. Seedlings were grown in a greenhouse. On 25th March 2014, seedlings with four to five true leaves were transplanted, open air, in soil. Plot area was 10.5 m^2.

Fertilizer 11-11-21 was applied at level 420 g/plot soon before transplanting of seedlings. Water soluble fertilizer was applied two times – 70 g/plot 24-8-16 and 35 g/plot 15-30-15. Total applied quantity of N, P_2O_5 and K_2O was 86.0, 74.7 and 115.3 kg/ha, respectively.

All recommended agricultural practices were adopted uniformly according to standard crop requirements. At first harvest on 12th May (7 days after the first foliar fertilization), the leaf sampling was done, and other (three) harvests were done on 23rd May, 2nd June and 12th June and the yields were measured. A completely randomized design with nine replicates was performed.

The soil samples from 0-30 cm depth were taken in each plot.

The basic soil parameters were determined by methods widely used in Former Republics of Yugoslavia (Džamić *et al.*, 1996). The content of available Fe, Mn, Zn and Cu (extraction with 0.005 M DTPA) as well as of exchangeable Mg (extraction with 1 M NH_4CH_3COO) in soil were determined by flame atomic absorption spectrometry (AA-6800, Shimadzu). The concentrations are expressed on air-dried basis.

After microwave digestion (Ethos 1) the samples of chard (edible portion) with HNO_3 and H_2O_2 (5:2), the total elemental concentrations (excluding N) were determined by ICP-OES (Spectro Arcos). Total nitrogen was determined by Kjeldahl method. The concentrations are expressed on dry matter (dried at 105°C).

The results were processed by means of the SPSS 16.0 Program. The statistical analyses included descriptive (mean and standard deviation), correlation (matrix not shown) and factor analysis.

RESULTS AND DISCUSSION

The descriptive statistics (minimal, maximal and mean values with standard deviation) of investigated soil and chard parameters are given in Tables 1 and 2. The content of dry matter in chard was 7.97%.

Table 1. Descriptive statistics for the soil

Parameter	Minimum	Maximum	Mean	Std.
pH (H_2O)	7.60	7.97	7.82	0.13
pH (KCl)	7.04	7.41	7.27	0.12
$CaCO_3$ (%)	2.3	38.1	18.1	13.1
Humus (%)	4.85	5.95	5.37	0.43
P_2O_5 (mg/100 g)	3.8	21.6	9.4	6.0
K_2O (mg/100 g)	16.2	23.4	20.4	2.4
EC (µS/cm)	145.4	158.8	152.5	4.9
Ca (mg/100 g)	698	2239	1767	674
Mg (mg/100 g)	18.6	25.3	22.5	2.7
Fe (mg/kg)	12.50	19.40	14.26	2.35
Mn (mg/kg)	7.00	12.70	8.88	1.91
Cu (mg/kg)	1.55	2.17	1.87	0.21
Zn (mg/kg)	1.23	2.83	1.86	0.49
Sand 2-0.2 mm (%)	3.43	8.64	5.85	1.90
Sand 0.2-0.02 mm (%)	30.31	57.06	42.72	8.75
Silt 0.02-0.002 mm	8.10	36.68	22.91	10.21
Clay <0.002 mm (%)	12.92	41.02	28.52	9.35
Total sand (%)	38.95	61.02	48.57	7.38
Total clay (%)	38.98	61.05	51.43	7.38

These neutral and alkaline soils, with low to very high content of total carbonates, rich and very rich in organic matter (humus), were very fertile considering the available fraction of nutrients (Table 1). Namely, the content of almost all nutrients ranged from medium to high level. Available fraction of phosphorus was mainly at low level.

Table 2. Descriptive statistics for the chard (concentration expressed on a dry matter)

Parameter	Minimum	Maximum	Mean	Std.
N (g/kg)	42.80	54.60	47.61	3.36
P (g/kg)	3.60	6.30	4.51	0.96
Ca (g/kg)	21.71	30.75	25.39	3.09
K (g/kg)	38.84	58.60	46.97	5.84
Mg (g/kg)	6.36	9.78	8.10	1.39
Na (g/kg)	14.92	27.34	20.86	4.54
Al (mg/kg)	61.82	163.45	97.24	41.33
B (mg/kg)	13.04	17.71	15.40	1.47
Ba (mg/kg)	34.86	56.08	43.06	6.76
Cu (mg/kg)	11.14	16.47	13.17	1.67
Fe (mg/kg)	94.64	144.64	111.86	19.83
Mn (mg/kg)	143.320	209.150	170.75	21.12
Sr (mg/kg)	10.16	13.50	11.61	1.02
Zn (mg/kg)	27.29	44.28	34.07	4.63
I_harvest (kg)	3.85	8.65	5.81	1.43
All_harvests (kg)	22.50	37.90	31.28	4.87

The results about soil texture include size classes – sand, silt and clay. Based on International Soil Science Society (ISSS) classification, there were the four textural classes: sandy clay, loam, light clay and clay loam.

The chemical analysis of the chard showed that content (expressed on dry mass) of potassium, sodium, magnesium, iron, zinc and copper was lower in comparison to the results of USDA National Nutrient Database for chard cooked, without salt (http://www.ars.usda.gov/ba/bhnrc/ndl). For mentioned elements concentrations were: 74.69 g/kg; 24.35 g/kg; 11.70 g/kg; 307.48 mg/kg; 44.90 mg/kg; and 22.18 mg/kg, respectively. Phosphorus was at similar level, but the content of calcium and manganese and protein (using conversion factor 6.25) were 3.2, 3.8 and 1.2-fold higher, respectively, than the concentrations given in database. This ratio for Ca was expected due to chard growing on calcareous soils. Results of Miceli and Miceli (2014) study indicated that reducing nitrogen fertilization of Swiss chard between 100 and 150 kg N/ha could lead to a more environmentally friendly product with no significant loss in yield and quality both for raw plant and minimally processed Swiss chard. The content of applied N in our study was below the mentioned range. Beside mentioned nutrients, the content of aluminium, strontium and barium also were determined. The chard harvested the first time (in mid-May) contained aluminium in the concentrations much less than 200 mg/kg of dry mass for the most plants (Mossor-Pietraszewska, 2001). The possibility that strontium or barium is essential has not been confirmed or denied. Strontium and barium, as chemically similar to calcium and magnesium, behave similarly during soil-to-plant transfer (He *et al.*, 2012). The concentration of barium was about 3-4 fold higher than of strontium. The yield achieved with four harvests was approx. 30 t/ha.

By factor analysis the original set of totally 24-correlated soil and chard parameters, were transformed into a new set of mutually uncorrelated factors (Table 3, Fig. 1) according to Topalović *et al.* (2006; 2010).

Table 3. Factor analysis for soil and chard: Eigenvalues, cummulative of the total variance, factor loading of the 3 factors, and communality estimates of the soil parameters

	Factor 1	Factor 2	Factor 3	Commun.
Eigenvalue	6.89	6.34	5.24	
Cumulative (%)	28.71	55.10	76.92	
P_2O_5	0.955			0.947
Zn	0.893			0.825
Ch_B	0.862			0.843
All_harvests	-0.845			0.781
K_2O	-0.731			0.826
Ch_P	0.673			0.791
Ch_K	-0.651		0.616	0.869
Mg	0.632			0.881
Ch_Zn				0.366
Ch_Mn		-0.880		0.818
pH (KCl)		0.796		0.766
pH (H_2O)		0.782		0.783
Fe		-0.729		0.824
Ch_Fe		0.701		0.814
Mn		-0.699		0.925
Ca		0.660		0.892
Ch_Cu		-0.630		0.405
Humus				0.601
Ch_N			0.910	0.891
Ch_Mg			0.859	0.906
Cu			-0.857	0.840
Ch_Ca			0.755	0.770
$CaCO_3$			0.675	0.229
EC				0.869

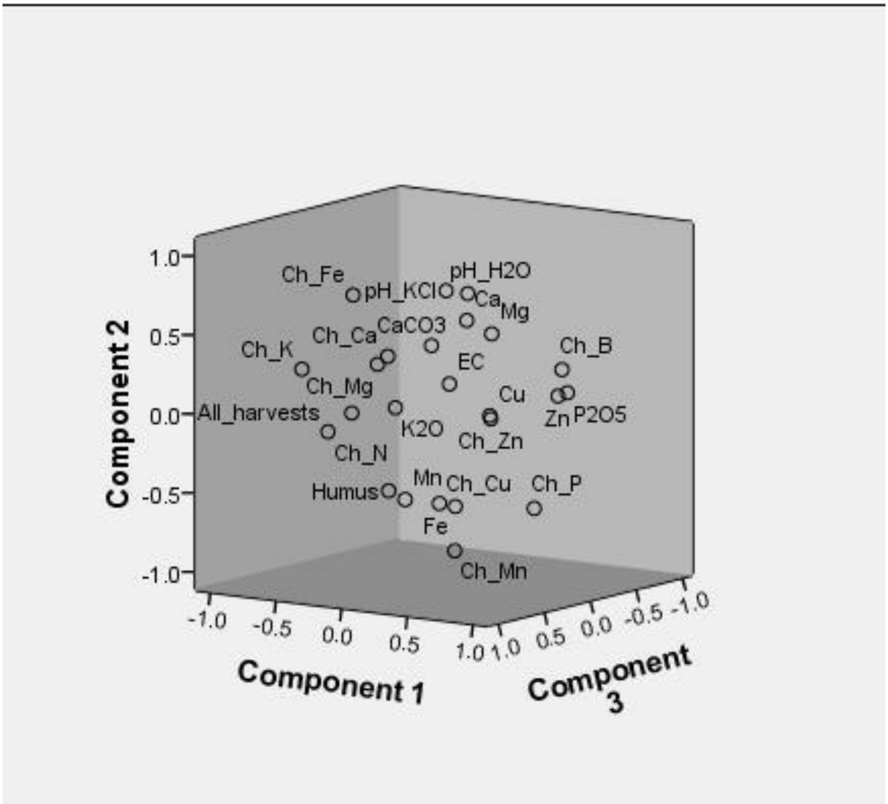

Figure 1. Component plot in rotated space

Three factors determining soil-chard relationships were identified by factor analysis (Table 3). They accounted for about 77% of the total variance. The communalities of soil parameters, considering three factors, varied from about 23% for total carbonates to 95% for available P_2O_5, and of chard parameters from about 37% for zinc and 91% for magnesium.

Factor 1 is composed from two complementary groups of parameters – first: available soil P, Zn, Mg, as well as boron and phosphorus in chard; second: yield (all harvests), and potassium in chard and available soil potassium.

Factor 2 is consisting from soil acidity, available Ca and chard Fe, and on the other side of chard Mn and Cu with available soil Mn.

Factor 3 has positive loadings for chard K, N, Mg, and Ca and total carbonates in soil, but negative for available soil Cu.

Generally, the nutrient uptake by chard can be affected by available fraction of nutrients. As seen from Table 3, the content of P, K and Mn in chard depended on its concentration in soil. However, Fe in chard was in negative correlation with soil Fe. It could be concluded that manganese uptake prevailed, because the concentration of Mn in chard was higher than of Fe (Table 1). The soil conditions were suitable from the aspect of availability of P, K, Ca and Mg, but less suitable for Fe, Mn, Zn and Cu because of soil pH above 6. The content of exchangeable soil Ca and Mg regulated the chard Ca and Mg. The opposite trend was noticed between soil pH and chard Mn and Cu. Because of relatively high concentration of all nutrients and high quantity of humus, the card was optimally supplied.

After critical assessment of all correlations, it could be assumed that the yield increased with the increase of available soil K.

CONCLUSIONS

The results of soil and leaf analysis indicated optimal conditions for chard growing. The quality and quantity of chard depended on soil properties. The content of P, K and Mn in chard depended on its concentration in soil and the chard Ca and Mg were regulated by the content of exchangeable soil Ca and Mg. The opposite trend was noticed between soil pH and chard Mn and Cu. The yield was in positive significant relationship with available soil K.

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VEZE IZMEĐU PARAMETARA ZEMLJIŠTA I BLITVE (*BETA VULGARIS* L. VAR. *CICLA* L.)

SAŽETAK

U radu su prikazani rezultati proučavanja veza između agrohemijskih parametara zemljišta (pH, ukupni karbonati, organska materija, pristupačne frakcije K, P, Ca, Mg, Fe, Mn, Zn i Cu) i nutrijenata u blitvi (*Beta vulgaris* L. var. *cicla* L.). Blitva je gajena na neutralnom i alkalnom zemljištu sa različitim agrohemijskim karakteristikama. Kvalitet i prinos blitve zavisili su od osobina zemljišta. Sadržaj P, K i Mn u blitvi zavisio je od koncentracije ovih elemenata u zemljištu, a Ca i Mg bio je regulisan sadržajem izmjenjivog Ca i Mg u zemljištu. Negativni trend je zapažen između zemljišnog pH i sadržaja Mn i Cu u blitvi. Prinos je bio u značajnoj pozitivnoj vezi sa pristupačnim kalijumom u zemljištu.

Ključne riječi: zemljište, blitva, nutrijent, veza