Effects of iron, manganese and zinc enriched coffee and tea wastes on lettuce – a field trial

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Abstract: Ensuring proper microelement supply under alkaline soil conditions could be a challenge even with the application of synthetic chelates. In this study, the application of coffee and tea wastes enriched with water soluble inorganic iron, manganese and zinc compounds was compared to water solution application of the same compounds at the same amount on a field with an alkaline Calcaric Arenosol. One butterhead and two iceberg lettuce cultivars were used as test plants. The effects of microelement enriched wastes on microelement availability in the soil, measured by DTPA-TEA method, was not clear-cut. However, the soil application of those microelement enriched wastes increased the nutritional value of lettuce by resulting in significantly higher concentration in cores for all the three investigated microelements. The highest rate of increase was observed for iron. As a consequence, lettuce heads accumulated significantly higher amount of iron, while this was not the case for manganese and zinc. There were comprehensive differences in the microelement concentration of the cores of the three investigated cultivars, with the butterhead type having especially high iron concentration. Head weights were not affected by the treatments. Hence, under the field conditions of this study, higher microelement concentration and uptake in the lettuce heads was not a prerequisite for good lettuce yield, as it was proved by the results of a zero control. However, the soil application of microelement enriched coffee and tea wastes for supplying microelements for lettuce in alkaline soil proved to be promising, especially for iron.

Keywords: iron, zinc, manganese, butterhead lettuce, iceberg lettuce

Introduction

Soil or irrigation water alkalinity limits production of vegetable crops in many parts of the World (Roosta, 2011). Alkaline soil and alkaline irrigation water are also quite common in Hungary (Jones et al., 2005; Rácz, 2007). Uptake of some microelements, for example iron, manganese and zinc, are especially restricted under alkaline conditions (Marschner, 1998; Füleky and Rajkainé Végh, 1999). In order to avoid yield loss and reduced nutritional value under alkaline conditions synthetic chelates are applied to provide available microelements for the plants. Several different carriers (EDTA, HEEDTA, DTPA, EDDHA, EDDHHA and NTA) are used to produce microfertilizer chelates (Hoffmann and Górecki, 2000 cited in Tyksinski and Komosa, 2008). Compared to a conventional, water soluble inorganic microelement compound (ferrous sulphate), application of chelates gave good results in soilless lettuce production (Roosta et al., 2015). However, these compounds can be very expensive; hence their use is often not cost effective (Roosta et al., 2015). Moreover, the application of these synthetic chelates is often less effective in soil culture. Even significantly decreased head weights and chelate excess symptoms as a result of Fe-EDTA+DTPA, Fe-DTPA and Fe-AM-4 applications were reported (Tyksinski and Komosa, 2007 cited in Tyksinski and Komosa, 2008; Kozik et al., 2011). Thus, there is a need for cheaper chelating agents which can be used effectively and economically even in open field production.

The use of agricultural waste products is a logical answer to the problem outlined above. Their volume is constantly increasing with growing population (Sönmez et al., 2017) and their organic matter content offers the possibility of containing potentially metal-chelating substances (Morikawa and Saigusa, 2008). Sönmez et al. (2017) applied greenhouse wastes, used coco peat and spent mushroom compost at different ratios for greenhouse-grown lettuce. Marketable yield increased compared to the control while iron and manganese concentration did not decrease. However, zinc concentration in the lettuce heads fertilized by compost became lower.

Coffee and tea are among the most popular beverages worldwide. Large amounts of coffee and tea wastes are produced by companies manufacturing coffee and tea beverages. These wastes should be reused on a sustainable way (Morikawa and Saigusa, 2008). It was found that coffee waste application to an Arenosol in the Democratic Republic of Congo promoted nutrient retention of this sandy soil besides of several other favourable physico-chemical changes (Kasongo et al., 2011). Coffee and tea are very rich in phenolic compounds which can act as metal chelating agents (Brown et al., 1998). Morikawa and Saigusa (2008) composted coffee grounds and tea leaf wastes together with ferrous-sulphate. Application of the resulting compost increased plant-available iron concentration in neutral and alkaline soils, and significantly enhanced iron content of Japanese leaf radish. Top-dressing application of microelement enriched coffee and tea waste materials was suitable to increase iron, manganese and zinc content of rice grains and to enhance grain yield (Morikawa and Saigusa, 2011).

Lettuce is rich in mineral nutrients (Rubatzky and Yamaguchi, 1997). Calcium, iron and phosphorus content of lettuce is especially high, and its manganese and zinc concentration is also considerable (Hartz et al., 2007). Bosiacki and Tyksinski (2009) found the highest manganese and zinc content in lettuce, out of nine investigated vegetable crops. Hence, effectiveness of microelement fertilisation has special importance in lettuce production, both in soil and soilless cultures. Accordingly, microelement fertilisation of lettuce has being extensively studied recently (Tiksinski and Comosa, 2008; Kozik et al., 2011; Roosta, 2011; Roosta et al. 2015; Sönmez et al., 2017).

The objective of this study was to investigate the effects of tea and coffee waste products enriched with water soluble inorganic microelement compounds, on iron, manganese and zinc concentration and uptake of lettuce heads under field conditions on an alkaline sandy soil in the central region of Hungary.

Material and methods

Climatic and edaphic conditions

The field trial was carried out in the horticultural experimental field of Szent István University (NL 47°35’, EL 19°21’) in 2013. The average air temperature of the cultivation period (22nd April – 14th June) was 16.8 ºC, while total precipitation was measured 134 mm. The used field was under constant intensive vegetable cultivation for almost six decades. The loamy sand soil of the field was classified as Calcaric Arenosol. According to measurements made in a soil suspension using a soil/deionised water ratio of 1:5, the soil of the exact site showed the following characteristics: pH 8.0, EC 0.61 mS cm^{-1}, organic matter content 1.1%. Iron, manganese and zinc concentrations of the soil were measured from both 0.1 mol L^{-1} HCl (Fe 25.2, Mn 116, Zn 29.0 mg kg^{-1}) and DTPA-TEA (diethylene-triamine-pentaacetic acid – triethanol amine) (Fe 16.3, Mn 16.6, Zn 9.0 mg kg^{-1}) extracts by an inductively coupled plasma (ICP-OES) instrument (Thermo Scientific iCAP 6000, Tokyo, Japan) following the methods of Jones & Case (1990) and Provin & Zhang (2014), respectively. Some chemical parameters of the irrigation water were the following: pH 7.25, EC 0.55 mS cm^{-1}, HCO_3^- 372 mg L^{-1}, Fe 0.3 mg L^{-1}, Mn and Zn under 0.01 mg L^{-1}.

Cultivation methods

Three lettuce cultivars were selected for the trial. A buterrhead type lettuce, ‘Jolito RZ’ (Rijk Zwaan Zaadteelt en Zaadhandel B.V.), a European iceberg type lettuce, ‘Diamanthinas RZ’ (Rijk Zwaan Zaadteelt en Zaadhandel B.V.) and a Japanese iceberg type lettuce, ‘V lettuce’ (Kaneko Seeds Co. Ltd). Unlike iceberg (or crisphead) lettuce, butterhead type does not form a firm, cabbage like core; hence the central part of the head is not separated from the outer leaves during harvest and selling. Seeds were sown into peat mixture filled plug seedling trays, having

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61 cm^3 plug volume, on 22nd March and raised in an unheated greenhouse. Basal fertilization was carried out by broadcasting on 21st April, providing nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) at 10, 11.8 and 13.9 g m^{-2} rate, respectively. Raised beds having 0.6 m width and 0.1 m height were formed on the same day. Distance between the centres of two neighbouring beds was 1.4 m. Beds were covered with black polyethylene mulch. Seedlings having 5 true leaves were transplanted on 22nd April into double rows. Distance between the rows and also distance between the plants in a row were 0.3 m. The field was equipped both with micro sprinkler and drip irrigation (20 mm i.d., 30 cm emitter spacing, 1.7 $L \cdot h^{-1}$ emitter discharge) systems. Irrigation was performed based on tensiometer readings. The amount of supplied irrigation water was 70 mm altogether. Nitrogen fertigation was applied on 17th and 25th of May through the drip irrigation system at 2.5 g m^{-2} rate at each occasion, using ammonium-nitrate as fertilizer. In accordance with their growing periods, the three cultivars were harvested at different dates, 'Jolito RZ' on 27th May, 'V Lettuce' on 6th June and Diamantinas on 10th June.

Treatments

Methods of microelement (Fe, Mn, Zn) supply meant the treatments. Three treatments and a zero control (CNT) were applied on 21th April. Plants of the CNT were not supplied by any microelement fertilizers. Microelement enriched coffee waste (MCW) and tea waste (MTW) were prepared from coffee grounds or from tea drags, respectively, following the method described by Morikawa & Shinohara (2013). Water soluble inorganic microelement compounds, 116 g iron-chloride ($FeCl_3$), 44 g manganese-sulphate ($MnSO_4*5H_2O$) and 44 g zinc-sulphate ($ZnSO_4*7H_2O$), were mixed to 796 g coffee or tea waste and used as microelement sources. MCW and MTW were mixed at 10 cm depth into the soil at 100 g m^{-2} rate simultaneously with bed formation. For an other treatment the same amount of inorganic microelement compounds (IMC) ($FeCl_3$ 11.6 g m^{-2}, $MnSO_4*5H_2O$ 4.4 g m^{-2}, $ZnSO_4*7H_2O$ 4.4 g m^{-2}, representing 4.00 g m^{-2} iron, 1.00 g m^{-2} manganese and 1.00 g m^{-2} zinc concentrations, respectively) were supplied alike for the microelement enriched waste treatments. Microelements were dissolved in water, distributed onto the surface of the plots and mixed into the soil thereafter at 10 cm depth.

A randomised split plot design with three replications was used. Each plot contained 42 plants arranged in double rows. Accordingly, width and length of a plot was 0.6 m and 6.3 m, respectively, and consisted of three 2.1 m long subplots each containing 14 plants, representing the three cultivars. Hence, area of a plot was 3.8 m^2.

Measurements

The six central plants were sampled from every subplot. Stems were cut at the soil level, and fresh weight of the whole heads, including all the outer leaves, was measured immediately. In the case of the two iceberg type cultivars the core and the outer leaves were divided, also weighed separately and handled as two samples. The samples were dried in an oven at 65°C until reaching constant weight, then dry weight was determined. Iron, manganese and zinc concentration of lettuce cores and outer leaves were measured from dry grounded samples by an ICP-OES instrument (Thermo Scientific iCAP 6000, Tokyo, Japan) using the method of Provin & Zhang (2014). Microelement uptake of above ground parts of lettuce plants were calculated based on these concentrations and dry weight data. An average soil sample was formed from six subsamples for every subplot. Samples were taken from the 0 to 0.1 m depth on 14th June. Soil samples were air dried for four days on room temperature and passed through a 2 mm sieve. Plant-available microelement concentration of these samples was determined by the method of Provin & Zhang (2014).

Statistical analysis

Differences in means were tested by a two-way ANOVA (with microelement fertilizer treatment and cultivar regarded as factors) and subsequent post-hoc comparisons of means (Fisher's protected least significant difference (LSD) test at P=0.05).

Results and Discussion

Concentration of iron, manganese and zinc in the soil

The method of microelement supply significantly affected the plant-available microelement concentration in the soil, while lettuce cultivar and fertilizer x cultivar interaction did not reveal a pronounced effect (Table 1). MCW application was the most effective, significantly increasing its plant-available concentration in the soil compared to MTW and IMC treatments. This result is in good agreement with the findings of Kasongo et al. (2011). MTW resulted in higher manganese concentration compared to MCW application, while significant differences in manganese level could not be detected neither between the IMC and MCW, and the IMC and MTW treatments.

Table 1. Effect of fertilizer type on plant available concentration of iron, manganese, zinc in the soil after lettuce cultivation, measured by DTPA-TEA method

Cultivar	Fertilizer	Iron (Fe)	Manganese (Mn) (mg kg^{-1})	Zinc (Zn)
'Jolito RZ'	CNT	16.7	18.1	7.7
	IMC	18.5	23.1	11.6
	MCW	20.4	19.7	12.2
	MTW	19.1	22.7	12.3
'V Lettuce'	CNT	16.7	18.4	8.0
	IMC	18.4	21.1	10.7
	MCW	21.3	21.1	12.1
	MTW	20.2	21.1	12.0
'Diamantinas RZ'	CNT	17.1	18.8	7.8
	IMC	20.0	22.0	9.9
	MCW	20.9	21.0	11.8
	MTW	19.6	25.7	11.4
LSD (P < 0.05)		2.2	3.0	1.6
			***P* value by factors**	
fertilizer		$9.96*10^{-6}$	$4.00*10^{-5}$	$1.84*10^{-9}$
cultivar		0.4395	0.1316	0.1859
fertilizer x cultivar interaction		0.8184	0.1867	0.7834
			Average by fertilizer treatments	
CNT		16.8	18.4	7.8
IMC		19.0	22.1	10.7
MCW		20.9	20.6	12.0
MTW		19.6	23.2	11.9
LSD 5%		1.3	1.7	0.9
			Average by cultivars	
'Jolito RZ'		18.7	20.9	10.9
'V Lettuce'		19.2	20.4	10.7
'Diamantinas RZ'		19.4	21.9	10.2

(CNT = Zero control; IMC = Inorganic microelement compounds; MCW = Microelement enriched coffee waste; MTW = Microelement enriched tea waste)

In the average of the three cultivars, all the three treatments increased plant-available iron, manganese and zinc concentration in the soil compared to the CNT. However, in regard of concentration, order of the treatments was different for the three investigated microelements. For iron, MCW application was the most Zinc concentration in the IMC treatment was significantly lower compared to the two waste product treatments, while MCW and MTW produced practically equivalent results. The measured values represent a high level of iron, manganese and zinc supply, even in the CNT plots (Stevens; Mahashabde and Patel, 2012).

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This could be the result of the long-time intensive farming and thus intensive fertilization in the experimental field.

Concentration of iron, manganese and zinc in the core

Both investigated factors and also their interaction significantly affected microelement concentration in the core (Table 2).

IMC treatment. Differences between the results of MCW and MTW treatments could not be proved statistically. IMC treatment significantly enhanced manganese and zinc concentration compared to the CNT, but this was not the case for iron. Rate of difference between the results of the CNT and the three treatments was bigger for manganese and zinc than for iron. Iron concentration in the butterhead lettuce was about eight times higher compared to the two iceberg cultivars (Table 2). This result is in agreement with the Japanese Food Composition Database. The USDA nutritional database (U.S. Department of Agriculture, 2015) also indicates higher iron content for butterhead (12.4 mg kg^{-1}) than for iceberg lettuce (4.1 mg kg^{-1}). Mou (2009) explained the lower nutrient

Table 2. Effect of fertilizer type on iron, manganese and zinc concentration (mg kg^{-1} fresh weight) in cores of three lettuce cultivars

Cultivar	Fertilizer	Iron (Fe)	Manganese (Mn) (mg kg^{-1} fresh weight)	Zinc (Zn)
‘Jolito RZ’	CNT	22.88	3.04	1.82
	IMC	23.95	2.94	1.88
	MCW	27.47	3.53	2.14
	MTW	28.43	3.67	2.16
‘V Lettuce’	CNT	2.47	0.94	1.57
	IMC	3.01	1.06	1.96
	MCW	3.77	1.18	2.08
	MTW	2.85	1.02	1.86
‘Diamantinas RZ’	CNT	2.79	0.90	1.61
	IMC	2.82	8.61	6.53
	MCW	3.42	8.93	7.06
	MTW	3.61	8.92	7.19
LSD (P < 0.05)		2.23	0.58	0.37
			***P* value by factors**	
fertilizer		0.0019	$1.19*10^{-15}$	$7.83*10^{-17}$
cultivar		$1.24*10^{-24}$	$5.03*10^{-23}$	$1.94*10^{-24}$
fertilizer x cultivar interaction		0.0182	$7.65*10^{-17}$	$3.56*10^{-17}$
			Average by fertilizer treatments	
CNT		9.38	1.63	1.67
IMC		9.93	4.20	3.46
MCW		11.56	4.54	3.76
MTW		11.29	4.54	3.74
LSD 5%		1.29	0.34	0.21
			Average by cultivars	
‘Jolito RZ’		25.68	3.29	2.00
‘V Lettuce’		3.02	1.04	1.87
‘Diamantinas RZ’		3.16	6.84	5.60
LSD 5%		1.11	0.29	0.18

(CNT = Zero control; IMC = Inorganic microelement compounds; MCW = Microelement enriched coffee waste; MTW = Microelement enriched tea waste)

Core of the lettuce is the consumed part; hence its microelement concentration has nutritional importance. Therefore it is of great importance that in the average of the three cultivars, application of both waste materials resulted in significantly higher concentration of all the three investigated microelements, compared to the content of the core of iceberg type lettuce compared to more open-headed lettuces with its closed structure, as the synthesis or absorption of many nutrients is light dependent. On the contrary Rubatzky and Yamaguchi (1997) listed very similar iron content for iceberg and butterhead lettuces. In their study Roosta et al. (2015) did not find significant differences in iron and zinc concentration of butterhead and iceberg lettuces either.

There were also comprehensive differences among the manganese and zinc concentration of the three cultivars, with ‘Diamantinas RZ’ having 4-6 times higher values compared to ‘V lettuce’, and three times higher values compared to the butterhead type ‘Jolito RZ’ (Table 2). It is supposed that these high concentrations were the main reason for that the extent of difference between the results of the treatments and the CNT was by far the biggest for ‘Diamantinas RZ’ manganese and zinc concentrations. Due to its higher manganese and zinc accumulating capacity this cultivar could exploit the higher plant-available microelement level of the soil ensured by the treatments (Table 1). Zinc concentration results for ‘Jolito RZ’ and ‘V lettuce’ were in good agreement with data of the USDA nutritional database (U.S. Department of Agriculture, 2015), which indicates 1.5 mg kg^{-1} value for iceberg and 2.0 mg kg^{-1} for butterhead lettuce.

Concentration of iron, manganese and zinc in the outer leaves

Outer leaves were investigated separately for the two iceberg type cultivars, as their weight equals the core weight. MTW treatment resulted in significantly the highest iron and manganese concentration in the outer leaves, while MCW did not increase them compared to the CNT (Table 3). All the three treatments increased zinc concentration compared to the CNT, with IMC treatment producing the highest value. In the

Table 3. Effect of fertilizer type on iron, manganese and zinc concentration in outer leaves of two iceberg type lettuce cultivars

Cultivar	Fertilizer	Iron (Fe)	Manganese (Mn)	Zinc (Zn)
			(mg kg^{-1} fresh weight)	
‘V Lettuce’	CNT	12.25	2.54	0.97
	IMC	9.45	2.54	1.73
	MCW	12.26	2.81	1.38
	MTW	19.68	3.60	1.62
‘Diamantinas RZ’	CNT	12.27	3.59	1.41
	IMC	11.24	3.31	1.83
	MCW	14.06	3.84	1.60
	MTW	15.67	4.55	1.65
LSD ($P < 0.05$)		2.79	0.81	0.42
			***P* value by factors**	
fertilizer		$5.96*10^{-6}$	0.0027	0.0046
cultivar		0.8820	$1.30*10^{-4}$	0.0674
fertilizer x cultivar interaction		0.0205	0.9514	0.4953
			Average by fertilizer treatments	
CNT		12.26	3.06	1.19
IMC		10.35	2.93	1.80
MCW		13.16	3.30	1.49
MTW		17.68	4.07	1.63
LSD 5%		1.98	0.57	0.30
			Average by cultivars	
‘V Lettuce’		13.41	2.87	1.43
‘Diamantinas RZ’		13.31	3.82	1.62
LSD 5%			0.40	0.21

(CNT = Zero control; IMC = Inorganic microelement compounds; MCW = Microelement enriched coffee waste; MTW = Microelement enriched tea waste)

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average of the two iceberg cultivars, iron content of the outer leaves was four times higher than that of the core (Table 2). This result is in good agreement with the findings of Mou and Ryder (2002). On the other hand zinc and manganese concentration in outer leaves of 'Diamanthinas RZ' was much smaller than that of the core, while this was not the case with 'V lettuce'.

Head weight

Core and head fresh weights and head dry weight were not affected by the fertilizer treatment and by treatment x cultivar interaction (Table 4). Kozik et al. (2011) did not find any significant differences either between their microelement fertilizer treatments, except for a yield decreasing effect of Fe-DTPA at the highest rate. However, our result is not in agreement with the findings of Morikawa and Saigusa (2008, 2011), who discovered higher leaf radish fresh weight and rice grain yield as a result of application of microelement enriched coffee and tea waste materials. As it was expected prior to the trial, the highest head weights were produced by 'Diamantinas RZ' and the lowest ones by the butterhead type 'Jolito RZ'.

Iron, manganese and zinc uptake of lettuce heads

As fertilizer treatments did not affect head weight results significantly, microelement uptake results showed similar tendency to the concentration data. Microelement uptake of lettuce heads was significantly affected not only by the two investigated factors but also by their interaction (Table 5). In the average of the three cultivars the two waste treatments resulted in significantly higher iron uptake compared to the CNT and to the IMC treatment. This latter treatment

Table 4. Effect of fertilizer type on head weight of three lettuce cultivars

Cultivar	Fertilizer	Core fresh weight (g)	Head fresh weight (g)	Head dry weight (g)
'Jolito RZ'	CNT	683	683	29.8
	IMC	742	742	30.0
	MCW	749	749	30.3
	MTW	742	742	31.2
'V Lettuce'	CNT	498	1064	48.7
	IMC	483	1065	49.2
	MCW	525	1112	47.0
	MTW	549	1131	53.0
'Diamantinas RZ'	CNT	857	1591	74.4
	IMC	877	1660	71.4
	MCW	849	1608	66.1
	MTW	869	1614	68.0
LSD ($P < 0.05$)		117	174	8.2
			***P* value by factors**	
fertilizer		0.6258	0.2566	0.4994
cultivar		$3.23*10^{-11}$	$5.09*10^{-16}$	$1.00*10^{-15}$
fertilizer x cultivar interaction		0.9193	0.4663	0.5243
			Average by fertilizer treatments	
CNT		679	1124	50.9
IMC		701	1194	50.2
MCW		705	1102	47.8
MTW		722	1166	50.7
LSD 5%		58	87	4.7
			Average by cultivars	
'Jolito RZ'		729	729	30.3
'V Lettuce'		514	1114	49.5
'Diamantinas RZ'		863	1597	70.0
LSD 5%		58	87	4.1

(CNT = Zero control; IMC = Inorganic microelement compounds; MCW = Microelement enriched coffee waste; MTW = Microelement enriched tea waste)

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Table 5. Effect of fertilizer type on iron, manganese and zinc accumulation in three lettuce cultivars

Cultivar	Fertilizer	Iron (Fe)	Manganese (Mn) (mg plant-[1])	Zinc (Zn)
'Jolito RZ'	CNT	15.62	2.08	1.25
	IMC	17.73	2.18	1.40
	MCW	21.10	2.72	1.60
	MTW	20.65	2.66	1.61
'V Lettuce'	CNT	8.16	1.91	1.33
	IMC	6.93	1.98	1.96
	MCW	13.01	2.65	1.96
	MTW	9.15	2.27	1.91
'Diamantinas RZ'	CNT	11.40	3.40	2.43
	IMC	11.35	10.17	7.16
	MCW	14.85	11.17	7.50
	MTW	13.53	10.46	7.21
LSD ($P < 0.05$)		2.99	1.15	0.74
			***P* values by factors**	
fertilizer		$2.36*10^{-5}$	$4.53*10^{-9}$	$8.21*10^{-10}$
cultivar		$9.94*10^{-12}$	$1.24*10^{-18}$	$2.93*10^{-19}$
fertilizer x cultivar interaction		0.3891	$3.67*10^{-9}$	$2.98*10^{-9}$
			Averages by fertilizer treatments	
CNT		11.73	2.46	1.67
IMC		12.00	4.78	3.51
MCW		16.32	5.51	3.69
MTW		14.44	5.13	3.58
LSD 5%		1.73	0.67	0.43
			Averages by cultivars	
'Jolito RZ'		18.78	2.41	1.47
'V Lettuce'		9.31	2.20	1.79
'Diamantinas RZ'		12.78	8.80	6.07
LSD 5%		1.50	0.58	0.37

(CNT = Zero control; IMC = Inorganic microelement compounds; MCW = Microelement enriched coffee waste; MTW = Microelement enriched tea waste)

did not enhance iron uptake. In average of the three cultivars, manganese and zinc uptake was significantly increased by all the three treatments. This latter result was mainly due to the three-fold increase in manganese and zinc uptake of 'Diamanthinas RZ' as the effect of the treatments.

There were comprehensive differences among the cultivars in the accumulation of microelements (Table 5). Despite its inferior weight 'Jolito RZ' had significantly the highest iron accumulation, and hence nutritional value, due to its very high iron concentration (Table 2). Manganese and zinc uptake was significantly the highest for 'Diamantinas RZ' due both to its higher head weight and to its higher manganese and zinc concentration. No significant differences in the uptake of these two microelements between 'Jolito RZ' and 'V lettuce' were found.

Conclusions

Application of microelement enriched coffee and tea wastes increased the nutritional value of lettuce by resulting in significantly higher concentration in cores for all the three investigated microelements (Fe, Mn, Zn). The highest rate of increase was observed for iron. There were comprehensive differences in the microelement concentration in the cores of the investigated cultivars, high iron content of 'Jolito RZ' and high manganese and zinc content of 'Diamantinas RZ' are worth noting. Although head weights were not affected by the treatments, due to the higher concentration, iron uptake was

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significantly higher in the microelement enriched waste treatments, in some agreement with the soil extract measurements. In contrast with some previous experiments conducted with the same waste materials the yield could not be increased by the investigated microelement fertilization method. Hence, under the field conditions of this study, higher microelement concentration and uptake in the lettuce heads was not a prerequisite for good lettuce yield, as it was proved by the results of a zero control. However, even under the high microelement level condition of the soil of the experimental field, the application of microelement enriched coffee and tea wastes for supplying microelements for lettuce in alkaline soil proved to be promising, especially for iron.

Newly developed techniques for recycle organic wastes like coffee and tea wastes will certainly increase the add-value of those wastes, whose disposal is currently an environmental concern, because presently they have few uses. These wastes are rich in polyphenols that can bind metals like iron, manganese and zinc, serving as a carrier for plant absorption, increasing the nutritional value of crops for human health.

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