LEAF NUTRITIONAL LEVELS IN PEACH AND NECTARINE GROWN IN SUBTROPICAL CLIMATE[1]

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ABSTRACT - The study evaluated the leaf nutritional levels of peach and nectarine trees under subtropical climate in order to improve the fertilization practices. The experiment was carried out in São Paulo state University, Botucatu, São Paulo State, Brazil. The experimental design consisted of subdivided plots, in which plots corresponded to cultivars and subplots to the leaf sample periods. The evaluated peach cultivars were: Marli, Turmalina, Precocinho, Jubileu, Cascata 968, Cascata 848, CP 951C, CP 9553CYN, and Tropic Beauty, and that of nectarine was 'Sun Blaze'. The sample periods were: after harvest, plants in vegetative period; dormancy; beginning of flowering and fruiting (standard sample). Results indicated significant variations in the levels of N, P, K, Ca, Mg, S, B, Cu, Fe, Mn and Zn for the sampling period and in N, Ca, Mg, S, B, Fe and Mn levels for the cultivars.
Index terms: *Prunus persica* var. *vulgaris*, *Prunus persica* var. *nucipersica*, mineral nutrition, phenology.

TEORES NUTRICIONAIS FOLIARES EM PESSEGUEIRO E NECTARINEIRA CULTIVADOS EM CLIMA SUBTROPICAL

RESUMO - O trabalho teve como objetivo avaliar os teores foliares de nutrientes das cultivares de pessegueiro e nectarineira, cultivados em clima subtropical, visando a fornecer subsídios às práticas de adubação da cultura nessas condições. O experimento foi realizado na Faculdade de Ciências Agronômicas, UNESP, Câmpus de Botucatu. O delineamento experimental empregado foi em parcelas subdivididas, em que ás parcelas corresponderam às cultivares avaliadas e as subparcelas às épocas de coleta das amostras foliares. As cultivares de pessegueiro avaliadas foram: Marli, Turmalina, Precocinho, Jubileu, Cascata 968, Cascata 848, CP 951-C, CP 9553-CYN e Tropic Beauty e da nectarineira 'Sun Blaze'. As épocas de coleta das amostras foram: 1 – após a colheita dos frutos, no período vegetativo (fevereiro); 2 – na dormência (maio); 3 – início do florescimento (agosto), e 4 – 13ª a 15ª semana após a plena floração, antes da colheita - frutificação (época padrão - outubro-novembro). Os resultados obtidos permitiram concluir que houve variações significativas para os teores de N, P, K, Ca, Mg, S, B, Cu, Fe, Mn e Zn em relação às épocas de amostragem e para N, Ca, Mg, S, B, Fe e Mn, para os teores nutricionais nas cultivares.
Termos para indexação: *Prunus persica* var. *vulgaris, Prunus persica* var. *nucipersica*, nutrição mineral, fenologia.

INTRODUCTION

Peach production in Brazil was 239,149 tons in 2008, and the harvested area was 21,326 ha (ANUÁRIO BRASILEIRO DA FRUTICULTURA, 2010). Located in a warmer climatic region, São Paulo State contributes with around 10% planted area and 23% national production, presenting 21.5 t/ha/year mean productivity, as well as economic potential for the cultivation of peach and nectarine trees. The state has the early fruit harvest as its great advantage not only over the main Brazilian producing regions, but also over most countries located in the Southern Hemisphere, such as Chile, Argentina, Uruguay and South Africa (PEREIRA et al., 2002).

In subtropical regions, specific procedures for orchard management are necessary, especially nutritional control, in which balanced and satisfactory mineral nutrition factors are related to good harvests at the stages of plant production and formation. Fructification and production for most temperate fruit plants, including peach trees, are

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initially associated with the suitable development of flower buds. Thus, nutritional and phytosanitary management, as well as suitable environmental conditions to break dormancy, are essential (NAVA et al., 2009). An adequate nutritional status of flowers leads to higher and effective fructification for most fruit species, and nutritional competition is also frequently associated with low fructification levels in several fruit trees. The competition for nutrients during flower bud differentiation originates malformed flowers, negatively affecting fructification (CROSSA-RAYNAUD et al., 1985).

Early defoliation is a serious and very common problem in the main peach producing regions in Brazil, especially in São Paulo State, where the temperatures of the cultivated areas are higher. According to Nava et al. (2009), early defoliation, caused by either environmental and nutritional issues or phytosanitary problems, usually decreases carbohydrate levels in the plants, affecting their fructification. Some reports in the literature consider that a suitable nutritional status of flower buds may overcome the effect of high temperatures during flowering due to the prolongation of the pistil receptivity time (GAO et al., 2002 and WOLUKAU et al., 2004).

Since nutritional management of peach and nectarine trees cultivated in subtropical regions is still little known, especially regarding leaf fertilization and different cultivar requirements, this study aimed to evaluate the leaf nutritional content for peach and nectarine cultivars at different phenological stages over the production cycle in order to provide information for fertilization techniques under those conditions.

MATERIAL AND METHODS

This experiment was carried out in the School of Agronomical Sciences, São Paulo State University (UNESP), Botucatu Municipality, São Paulo State, Brazil, at 22º 51' 55" S, 48º 27' 22" W and 810m altitude. The climate of this region is mesothermal, *Cwa*, i.e. subtropical humid including drought during the winter and rain from November to April; mean annual precipitation is 1,433mm and mean annual temperature, 19.3 ºC (Cunha et al., 1999). The soil was classified as Red Nitosol, according to Embrapa's criteria (1996). At 0−20cm depth, the following chemical characteristics were detected for the soil: pH ($CaCl_2$) = 5.4; OM = 35 g dm^{-3}; P (resin) = 16 mg dm^{-3}; H +Al = 27 $mmol_c$ dm^{-3}; K = 3.7 $mmol_c$ dm^{-3}; Ca = 28 $mmol_c$ dm^{-3}; Mg = 13 $mmol_c$ dm^{-3}; SB = 45 $mmol_c$ dm^{-3}; CEC = 72 $mmol_c$ dm^{-3}; V = 63%, which were analyzed according to RAIJ & QUAGGIO (1983).

The plants from the experimental area aged 7 years and were spaced 6.0m between plants x 4.0m between rows, in a dryland area. The rootstock 'Okinawa' was used for all canopy cultivars. To assure the good development of plants, cultural and phytosanitary procedures were performed during the whole experimental period by following technical recommendations (PEREIRA et al., 2002).

Samples of recently mature complete leaves (blade with petiole) were harvested from the medium portion of current-year branches in the different plant quadrants (Malavolta et al., 1997). Eight leaves were harvested from each plant, totaling three plants per plot, with four replicates. The total sample was composed of 96 leaves for each evaluated cultivar. The levels of the nutrients N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, and Zn were quantified, according to the methodology proposed by Malavolta et al. (1997), in the Laboratory of Plant Mineral Nutrition. Harvests occurred: 1 – after fruit harvest, at the vegetative stage (February); 2 – during the dormancy period (May); 3 – at flowering beginning (August); and 4 – from the 13^{th} to the 15^{th} week after full flowering, before harvest − fructification (October−November); this period is considered ideal to compare leaf patterns (LEECE & BARKS, 1974; JOHSON & URIU, 1989; FREIRE & MAGNANI, 2003).

The peach cultivars Marli, Precocinho, Turmalina, Jubileu, Cascata 968, Cascata 848, CP 951-C, CP 9553-CYN, and Tropic Beauty, as well as the nectarine cultivar 'Sun Blaze', were evaluated.

The experimental design was subdivided plots, in which plots corresponded to the cultivars evaluated, and the subplots, to the leaf harvests in 2009. The obtained results were subjected to analysis of variance and, as for significance, means were compared by Tukey's test at 1 and 5% probability.

RESULTS AND DISCUSSION

There were significant variations in the levels of N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, and Zn according to harvests (Tables 1 to 6), which confirms that the uptake of mineral elements by peach trees varies with the plant physiological stages over the production cycle. The highest levels of N, S, B, and Zn were detected at the third harvest, corresponding to the onset of flowering. As regards P levels, the highest values were obtained at the third (flowering onset) and fourth (fructification) harvests. K and Ca levels were highest in the fructification period (fourth harvest), which corroborates the statement that these elements are essential to fruit quality in this period. The highest Mg and Mn levels were observed in the dormancy period (second harvest). At the first (after collection) and third (flowering onset) harvests, Cu levels were highest. Fe was highest at the second (dormancy) and third (flowering onset) harvests.

Johnson et al. (2006) emphasize that, although leaf sampling is worldwide recommended during the fructification stage, when the requirement for most nutrients is highest since fruits are the strongest plant drains, other periods can lead to better uptake of different nutrients, as observed in the present study. These authors also reported that leaf sampling during fructification can be considered very late to fulfill the fertilization requirements of the annual growth season. Based on this statement, the same authors evaluated leaf harvest during the dormancy period and observed a good response for N, P, B, and Zn. In their opinion, the other nutrients did not present response because deficiency symptoms had not been induced yet.

As regards the leaf content considered suitable for peach and nectarine trees, Leece & Barks (1974) reported the following international patterns: N (3.0−3.5%), P (0.14−0.25%), K (2.0−3.0%), Ca (1.8−2.7%), Mg (0.30−0.80%), Na (<0.02%), Cl (<0.3%), Fe (100−250 $\mu g\ g^{-1}$), Cu (5−16 $\mu g\ g^{-1}$), Mn (40−160 $\mu g\ g^{-1}$), Zn (20−50 $\mu g\ g^{-1}$), and B (15−19 $\mu g\ g^{-1}$). Johnson & Uriu (1989), in the United States, reported the following levels as optimal range: N (2.6-3.0%), P (0.1−0.3%), K (>1.2%), Ca (>1.0%), Mg (>0.25%), Fe (> 60 ppm), Mn (> 20 ppm), Zn (> 20 ppm), B (20−80 ppm), and Cu (> 4 ppm). The Soil Fertility Commission of Rio Grande do Sul State, Brazil (1994), set normal nutritional ranges for peach leaf samples, at the following levels: N (3.24−4.53%), P (0.15−0.28%), K (1.31−2.06%), Ca (1.64−2.61%), Mg (0.52−0.83%), Fe (100−230 mg kg^{-1}), Mn (31−160 mg kg^{-1}), Zn (24−37 mg kg^{-1}), Cu (6−30 mg kg^{-1}), and B (34−63 mg kg^{-1}).

The present results for the levels of N, P, K, Cu, Mn, Zn, and Fe were within the normal range, although there were differences regarding leaf harvests. Ca and Mg levels were below the recommended patterns, whereas B levels were above those values. S levels could not be compared since there were no reports on this element in the literature.

As regards nutrient uptake by the different evaluated cultivars, there were significant variations in the levels of N, Ca, Mg, S, B, Fe, and Mn, with different responses according to the nutrient. In general, leaf macronutrient uptake by the evaluated cultivars was in the following order: N>K>Ca>P>Mg>S. For micronutrients, the order was: Fe>Mn>B>Zn>Cu. According to Fachinello et al. (1996), nutrient export (kg/t) by fruits, pruned branches and leaves is: N (3.5), P_2O_5 (1.05) and K_2O (5.5), without considering the growth of peach trees. Malavolta (1980) reported that the levels of macronutrients (kg/ha) exported over peach fruit harvests (kg/ha) are: N (70); P(6); K (40); S (4); Ca (1.2); and Mg (2.4).

The results of the present study agree with those in the specialized literature, which state that nitrogen presents the highest uptake and the highest influence on peach tree productivity (Rombolá et al., 2000) since it directly affects the vegetative branch growth (Mattos et al., 1991), the number of vegetative and flower buds, and the number of fruits per plant. This nutrient can provide a longer period of leaf permanence, consequently increasing the period of reserve accumulation for the subsequent cycle (SERRAT et al., 2004). However, excessive supply can lead to oversprouting, which results in excessive shading, decreasing the fruit exposure to sunlight (MATTOS et al., 1991).

TABLE 1 – Nitrogen and phosphorus levels (g kg^{-1}) in leaf samples of peach and nectarine cultivars at different harvests. Botucatu, 2009.

	HARVESTS				
CULTIVARS	1	2	3	4	Mean
	Nitrogen levels (g kg^{-1})				
Turmalina	43 Aa	35 ABb	47 Ba	34 ABCb	40 A
Cascata 968	39 ABCa	30 Bb	42 BCa	32 ABCb	36 AB
Cascata 848	37 ABCb	36 ABb	45 BCa	34 ABCb	38 AB
Precocinho	40 ABb	39 Ab	48 ABa	28 Cc	39 A
CP 9553	37 ABCb	32 ABbc	44 BCa	29 BCc	36 AB
CP 951	32 Cb	31 Bb	39 Ca	32 ABCb	34 B
Marli	39 ABCb	31 Bc	47 BCa	37 Ab	38 A
Tropic Beauty	32 Cb	34 ABb	44 BCa	36 ABb	37 AB
Sun Blaze	34 BCb	31Bb	56 Aa	33 ABCb	38 A
Jubileu	34 BCb	32 ABb	43 BCa	34 ABCb	36 AB
Mean	37 b	33 c	45 a	33 c	37
	Phosphorus levels (g kg^{-1})				
Turmalina	2.5	2.3	4.1	3.5	3.1 A
Cascata 968	2.8	2.0	3.5	3.4	2.9 A
Cascata 848	2.4	2.3	3.8	3.4	3.0 A
Precocinho	2.7	2.7	4.6	3.5	3.4 A
CP 9553	2.7	2.4	3.9	3.4	3.1 A
CP 951	2.3	2.0	4.0	3.6	3.0 A
Marli	2.8	2.0	4.4	3.8	3.2 A
Tropic Beauty	2.2	2.1	4.0	14.2	5.6 A
Sun Blaze	2.6	2.3	4.3	3.8	3.2 A
Jubileu	2.7	2.2	3.8	3.3	3.0 A
Mean	2.6 B	2.2 B	4.0 AB	4.6 A	3.4

Means followed by different uppercase letters in the column and lowercase letters in the line differed according to Tukey's test at 5% significance.

TABLE 2 – Potassium and calcium levels (g kg^{-1}) in leaf samples of peach and nectarine cultivars at different harvests. Botucatu, 2009.

	HARVESTS				
CULTIVARS	1	2	3	4	Mean
K	Potassium levels (g kg^{-1})				
Turmalina	15 BCc	23 Ab	18 Ac	27 ABa	21 A
Cascata 968	16 ABCc	19 ABbc	20 Aab	22 CDa	19 A
Cascata 848	18 ABCab	17 ABb	17 ABab	21 Da	18 A
Precocinho	14 Cc	19 Bb	16 ABbc	23 BCDa	18 A
CP 9553	19 ABb	18 ABb	20 Aab	23 ABCDa	20 A
CP 951	18 ABCc	22 Ab	13 Bd	26 ABCa	20 A
Marli	15 ABCb	20 ABa	16 ABb	23 ABCDa	18 A
Tropic Beauty	20 Aab	16 Bb	18 Ab	22 CDa	19 A
Sun Blaze	18 ABCc	22 Ab	18 ABbc	27 Aa	21 A
Jubileu	17 ABCb	22 Aa	18 ABb	23 ABCDa	20 A
Mean	17 c	20 b	18 c	24 a	20
	Calcium levels (g kg^{-1})				
Turmalina	8 ABb	15 ABa	6 Ab	12 Aa	10 A
Cascata 968	4 Bc	10 Ca	5 Abc	8 Aab	7 B
Cascata 848	6 ABb	14 ABCa	6 Ab	11Aa	9 AB
Precocinho	5 ABc	15 ABCa	6 Ac	9 Ab	9 AB
CP 9553	5 ABb	13 ABCa	6 Ab	11 Aa	9 AB
CP 951	5 Bb	11 BCa	6 Ab	8 Aab	8 AB
Marli	8 ABb	13 ABCa	8 Ab	8 Ab	9 AB
Tropic Beauty	10 Ab	16 Aa	7 Ab	8 Ab	10 A
Sun Blaze	5 Bb	15 ABCa	6 Ab	12 Aa	9 AB
Jubileu	6 ABc	13 ABCa	7 Abc	10 Aab	9 AB
Mean	6 c	13 a	6 c	10 b	9

Means followed by different uppercase letters in the column and lowercase letters in the line differed according to Tukey's test at 5% significance.

TABLE 3 – Magnesium and sulfur levels (g kg^{-1}) in leaf samples of peach and nectarine cultivars at different harvests. Botucatu, 2009.

	HARVESTS				
CULTIVARS	1	2	3	4	Mean
	Magnesium levels (g kg^{-1})				
Turmalina	3.2 ABab	3.8 Ba	2.3 AB	3.7 Aa	3.2 AB
Cascata 968	2.3 Bab	3.2 Ba	2.1 ABb	3.0 Aab	2.7 B
Cascata 848	2.9 ABab	3.5 Ba	2.4 ABb	3.7 Aa	3.1 AB
Precocinho	2.6 Bbc	4.1 Ba	2.2 ABc	3.3 Aab	3.0 AB
CP 9553	2.7 Bab	3.6 Bb	2.3 ABb	3.5 Ab	3.0 AB
CP 951	3.1 ABab	3.0 Bab	2.3 ABb	3.3 Aa	2.9 AB
Marli	4.0 Aa	3.9 Bab	3.2 Aab	3.0 Ab	3.5 A
Tropic Beauty	3.3 ABb	5.5 Aa	2.4 ABb	2.8 Ab	3.5 A
Sun Blaze	2.5 Bb	3.9 Ba	2.0 Bb	3.6 Aa	3.0 AB
Jubileu	2.8 Ba	3.2 Ba	2.5 ABa	2.8 Aa	2.8 AB
Mean	2.9 d	3.8 a	2.3 c	3.3 b	3.1
	Sulfur levels (g kg^{-1})				
Turmalina	1.7 Aa	1.3 ABb	1.7 BCa	1.3 Ab	1.5 ABC
Cascata 968	1.6 ABa	1.4 ABa	1.5 Ca	1.4 Aa	1.5 BC
Cascata 848	1.4 ABa	1.5 ABa	1.5 Ca	1.5 Aa	1.5 ABC
Precocinho	1.5 ABb	1.7 Aab	2.0 ABa	1.5 Ab	1.7 AB
CP 9553	1.4 ABb	1.5 ABab	1.8 BCa	1.6 Aab	1.5 ABC
CP 951	1.2 Bb	1.4 ABab	1.6 BCa	1.3 Aab	1.4 C
Marli	1.4 ABb	1.4 ABb	2.0 ABa	1.5 Ab	1.6 ABC
Tropic Beauty	1.1 Bc	1.5 ABab	1.9 ABCa	1.5 Abc	1.5 ABC
Sun Blaze	1.3 Bb	1.2 Bb	1.9 ABCa	1.4 Ab	1.4 BC
Jubileu	1.3 ABb	1.6 ABb	2.3 Aa	1.6 Ab	1.7 A
Mean	1.4 b	1.5 b	1.8 a	1.5 b	1.5

Means followed by different uppercase letters in the column and lowercase letters in the line differed according to Tukey's test at 5% significance.

TABLE 4 – Boron and copper levels (mg kg^{-1}) in leaf samples of peach and nectarine cultivars at different harvests. Botucatu. 2009.

	HARVESTS				
CULTIVARS	1	2	3	4	Mean
			Boron levels (mg kg^{-1})		
Turmalina	67 ABb	50 Ab	130 Da	53 Ab	75 B
Cascata 968	93 Ab	46 Ac	135 CDa	51 Ac	81 AB
Cascata 848	84 ABb	48 Ac	178 Ba	46 Ac	89 AB
Precocinho	75 ABb	51 Ab	133 Da	50 Ab	77 B
CP 9553	81 ABb	47 Ac	136 CDa	48 Ac	78 B
CP 951	76 ABb	56 Ab	171 BCa	50 Ab	88 AB
Marli	61 ABb	58 Ab	136 CDa	35 Ab	72 B
Tropic Beauty	55 Bb	52 Ab	128 Da	62 Ab	74 B
Sun Blaze	98 Ab	56 Ac	150 BCDa	54 Ac	89 AB
Jubileu	91 ABb	47 Ac	229 Aa	52 Ac	105 A
Mean	78 b	51 c	152 a	50 c	83
			Copper levels (mg kg^{-1})		
Turmalina	10 Ba	10 Aa	11 ABCa	10 ABCa	10 A
Cascata 968	11 Bab	10 Ab	14 Aa	9 ABCDb	11 A
Cascata 848	12 ABa	8 Ab	12 ABa	7 BCDb	10 A
Precocinho	12 ABa	8 Ab	14 Aa	6 Db	10 A
CP 9553	15 Aa	8 Ab	14 Aa	6 Db	11 A
CP 951	11 ABa	9 Aa	9 BCa	11 ABa	10 A
Marli	11 Ba	9 Aab	7 Cb	11 ABa	9 A
Tropic Beauty	13 ABa	10 Aa	11 ABa	11 Aa	11 A
Sun Blaze	13 ABa	8 Ab	14 Aa	8 ABCDb	11 A
Jubileu	11 Bab	9 Abc	13 ABa	7 CDc	10 A
Mean	12 a	9 b	12 a	9 b	10

Means followed by different uppercase letters in the column and lowercase letters in the line differed according to Tukey's test at 5% significance.

TABLE 5 – Iron and manganese levels (mg kg^{-1}) in leaf samples of peach and nectarine cultivars at different harvests. Botucatu. 2009.

	HARVESTS				
CULTIVARS	1	2	3	4	Mean
	Iron levels (mg kg^{-1})				
Turmalina	81 Ab	150 Aa	128 BCa	80 Ab	110 AB
Cascata 968	93 Aa	132 Aa	104 Ca	102 Aa	108 AB
Cascata 848	90 Ab	140 Aa	99 Cab	130 Aab	115 AB
Precocinho	78 Ab	122 Aa	102 Cab	114 Aab	104 B
CP 9553	76 Ac	122 Ab	168 Ba	124 Ab	123 AB
CP 951	70 Ac	118 Ab	170 Ba	88 Abc	112 AB
Marli	79 Ac	136 Ab	228 Aa	89 Ac	133 A
Tropic Beauty	77 Ac	122 Aab	125 BCa	82 Abc	101 B
Sun Blaze	70 Ab	124 Aa	93 Cab	104 Aab	98 B
Jubileu	102 Ab	152 Aa	105 Cb	116 Aab	119 AB
Mean	82 c	132 a	132 a	103 b	112
	Manganese levels (mg kg^{-1})				
Turmalina	63	113	65	87	82 B
Cascata 968	67	135	84	103	97 AB
Cascata 848	84	175	97	125	120 AB
Precocinho	75	112	75	99	90 AB
CP 9553	53	142	67	85	87 AB
CP 951	75	80	94	87	84 AB
Marli	65	129	73	78	86 AB
Tropic Beauty	76	84	78	83	80 B
Sun Blaze	60	95	57	77	72 B
Jubileu	107	149	141	132	132 A
Mean	72 c	121 a	83 bc	96 b	93

Means followed by different uppercase letters in the column and lowercase letters in the line differed according to Tukey's test at 5% significance.

TABELA 6 – Zinc levels (mg kg-1) in leaf samples of peach and nectarine cultivars at different harvests. Botucatu. 2009.

	HARVESTS				
CULTIVARS	1	2	3	4	Mean
	Zinc levels (mg kg-1)				
Turmalina	14 ABb	15 Ab	27 Aa	26 Aa	21 A
Cascata 968	23 Aa	13 Ab	29 Aa	21 Aab	22 A
Cascata 848	15 ABbc	15 Ac	30 Aa	25 Aab	21 A
Precocinho	16 ABc	12 Ac	38 Aa	27 Ab	23 A
CP 9553	25 Aa	15 Ab	32 Aa	25 Aa	24 A
CP 951	12 Bb	15 Ab	30 Aa	28 Aa	21 A
Marli	16 ABc	12 Ac	38 Aa	25 Ab	23 A
Tropic Beauty	18 ABc	14 Ac	38 Aa	27 Ab	24 A
Sun Blaze	15 ABbc	12 Ac	29 Aa	22 Aab	19 A
Jubileu	17 ABb	10 Ab	34 Aa	27 Aa	22 A
Mean	17 c	13 d	32 a	25 b	22

Means followed by different uppercase letters in the column and lowercase letters in the line differed according to Tukey's test at 5% significance.

CONCLUSIONS

1. There were variations in the levels of N, Ca, Mg, S, B, Fe, and Mn for the different cultivars, with different responses according to the nutrient. As regards harvests at the different phenological stages of the peach tree, there was a difference in the leaf level of all evaluated nutrients.
2. In general, macronutrient uptake by the evaluated cultivars was in the following order: N>K>Ca>P>Mg>S. The order for micronutrient uptake was: Fe>Mn>B>Zn>Cu.

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