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SCHIMBĂRI ALE ELEMENTELOR MINERALE ESENȚIALE DIN FRUNZELE DE PIERSIC ÎN TIMPUL SEZONULUI DE CREȘTERE
CHANGES OF ESSENTIAL MINERAL ELEMENTS IN PEACH LEAVES DURING THE GROWING SEASON

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Abstract

The study was conducted during the period 2023-2024 in a fruit-bearing peach orchard on the territory of the Fruit-Growing Institute of Plovdiv. Changes in the content of N, P, K, Ca, Mg, and Fe in the leaves of three peach cultivars ('Cresthaven', 'Glohaven', and 'Redhaven') were monitored during the vegetation growing season. Regression equations were derived, expressing the dependence between the content of nutrients and the time of sample collection, which enabled the prediction of nutrient content throughout the growing season with a high degree of accuracy. Complex synergistic and antagonistic relationships were established, which varied depending on the plant development stage and the cultivar. A clearly expressed synergistic relationship between K/Fe at 60 and 120 days after full bloom (DAFB) in the three studied cultivars. In 'Glohaven' and 'Redhaven', a positive correlation was reported between P and K, as well as between P and Fe. Strong antagonism was found between N/K, N/Ca, and N/Fe, especially at higher nitrogen concentrations in the early stages of tree development.

Cuvinte cheie: piersic, analiza frunzelor, dinamica nutrienților, sinergism, antagonism.
Key words: peach, leaf analysis, nutrient dynamics, synergism, antagonism.

1. Introduction

Diagnosing the nutritional status of plants is crucial for achieving success in modern and competitive agriculture (Conceição et al., 2024). The mineral content of leaves is used to identify nutritional deficiencies, excesses, or imbalances in fruit crops (Montañés et al., 1991; Chatzisavvidis et al., 2005; Başar, 2006; Treder et al., 2022). The mineral composition of leaves was influenced by the plant's development stage at the time of sampling, the climatic conditions, the availability of nutrients in the soil, the root systems architecture and activity, the irrigation regime, and other factors. The tree integrated all those factors, and the mineral composition of the leaves reflected the result of that integration. Foliar diagnostics has been the most widely used method for determining the nutrient requirements of trees (Ryser et al., 2003; Roversi et al., 2008; Jiménez et al., 2004; Reil, W., 2002; Matsuoka Kaori, 2020; Huang et al., 2022). In order to be effective, it was necessary to establish seasonal variations in the nutrient concentrations in the leaves, so as to calculate the exact nutrient requirements during the growing season (Nachtigall and Dechen, 2006, Küçükyumuk et al., 2012, Shahkoomahally, S. et al., 2020). Identifying and filling N, P, and K deficiencies at an early stage of plant development was a key factor in ensuring good tree growth. Therefore, N, P, and K were the nutrients that should be monitored as a priority in mineral nutrition management (Li W et al., 2023).

The present study aimed to monitor the changes in the concentrations of mineral nutrients in the leaves of three peach cultivars during the vegetation growing season.

2. Material and methods

The study was conducted from 2023 to 2024 in an experimental field of the Fruit-Growing Institute in Plovdiv. The peach cultivars 'Cresthaven', 'Glohaven', and 'Redhaven' were the object of the study. The soil in the experimental plot was an alluvial meadow, characterized by a neutral to slightly alkaline soil reaction and well-stocked with phosphorus and potassium. Agrotechnical practices for cultivating the experimental plantation were carried out using conventional technology.

Samples for the leaf analysis were collected three times during the growing season in May, at 60 days after full bloom (DAFB), July (120 DAFB), and September (180 DAFB), respectively, from fifteen trees per cultivar, each tree being a separate replication. Leaf samples were taken randomly from both sides of the tree crown, from the middle part of the annual shoots (each sample contained

30 leaves). They were analysed for N, P, K, Ca, Mg, and Fe contents by variants and replications. The content of the studied elements was determined using the established analytical methods in agrochemical practice: nitrogen – by the method of Kjeldahl – by distillation; potassium – by the flame photometric method; phosphorus and iron – spectrophotometrically; calcium and magnesium – complexometrically. The statistical analysis of the data was carried out according to the Duncan MRT (De Mendiburu, 2021). Pearson's correlation coefficients were calculated to analyse the relationships between the variables.

3. Results and discussion

Monitoring the changes in the mineral element content of peach tree leaves during the different stages of vegetation provided valuable information for the optimal management of plant nutrition and prediction of their content. The results obtained showed that the supply of leaves with N, P, K, Ca, Mg, and Fe differed both between the cultivars and the vegetation periods (Table 1).

The mineral composition of the leaves varied within certain limits according to the growth stages.

The nitrogen content gradually decreased towards the end of the vegetation period, with a variation between the studied cultivars ranging from 3.51% for 'Cresthaven' at 60 DAFB to 1.62% for 'Glohaven' at 180 DAFB. Varietal differences were also observed. 'Cresthaven' cv. was distinguished by the highest nitrogen content throughout the entire period of vegetation, and 'Glohaven' cv. by the lowest N content, the differences being statistically significant. At the beginning of the vegetation season, the amount of nitrogen was sufficient, followed by a gradual decrease, toward values approximately 50% lower at 180 DAFB than at 60 DAFB. That decrease was probably due to the intensive absorption of the available nitrogen forms from the soil, in the absence of additional fertilization. Similar results were reported by Treder and Cieśliński (2003); Mahmood, et al. (2023); Chawla and Kumar Sharma (2024).

Phosphorus dynamics were characterized by a gradual decrease in concentration from 60 DAFB to 180 DAFB. No significant differences were observed between the cultivars at 120 DAFB and 180 DAFB (Table 1). Such results could be considered normal, since the tree's need for phosphorus is greatest at the beginning of the vegetation period and especially during the stage of cell division in the fruits. P is an element involved in the energy metabolism, nucleic acids, and membrane phospholipid composition (Kamerlin et al., 2013). The phosphorus content in the leaves throughout the vegetation period was within the optimal range for peach.

Seasonal changes in potassium levels were expressed in a decrease in its concentration from 60 DAFB to 180 DAFB in all three cultivars. The potassium content was significantly higher in 'Redhaven' cv. (3.04%), followed by 'Glohaven' (2.82%) at 60 DAFB. In September (180 DAFB), the concentration of the element decreased to 1.3 – 1.88%. There was a high need for potassium during fruit setting and maturing. Potassium is highly mobile and it was redistributed from the leaves to the fruits during the vegetation period, which led to a decrease in its content in the leaves. Similar results were also observed by Abenina et al. (2022). Depletion of potassium in the peach leaves might be caused by the dilution effect that occurred in parallel with leaf development and the redistribution of nutrients to the fruit, which highlights the seasonal dynamics of mineral nutrition in fruit trees Gerosa Ramos et al., 2019).

The dynamics of calcium changes in the leaves confirmed the opinion that as the vegetation progressed, its content increased. The established values for the calcium content in the leaves of the studied cultivars varied from 2.48% to 3.93%, corresponding to the optimal concentration for the nutrient. The increase in calcium content during the vegetation season made plants become more resistant to stress conditions, such as water deficit, and to diseases (Ramos and Jiménez, 2015).

Magnesium plays a key role in photosynthetic intensity, as it is a constituent of chlorophyll and participates in numerous enzymatic reactions (Nachtigall and Dechen, 2006; Marschner, 2012; Ahmed et al., 2023). The magnesium content in the leaves was strongly dependent on the phenological stage of the plant, particularly during bloom and fruit setting. Magnesium levels remained high in the three studied cultivars (0.52 – 0.85%) throughout all the stages of vegetation, indicating that the plant was able to maintain its needs for the element even in conditions of changing needs for other elements like potassium and calcium (Mota, et al. 2022). The highest values were observed at 120 DAFB, which corresponds to the period of most active photosynthesis.

Iron had a low mobility and its uptake by trees occurred in small amounts. Fe deficiency could have a significant impact on yield, fruit size and fruit quality (Kobayashi & Nishizawa (2012), Ahmadi et. al, 2022). A decrease in the iron content was observed towards the end of the vegetation season;

nevertheless, the concentrations determined for all three cultivars were within optimal limits (75.91 – 115.71 mg/kg).

The experimental data showed that changes in the content of the essential nutrients in the leaves of the peach cultivars 'Cresthaven', 'Glohaven', and 'Redhaven' were linearly dependent on the time of sample collection. The established correlations and regression models showed that the macronutrients nitrogen, potassium and phosphorus followed similar decreasing trends during the growing season, while the content of calcium and magnesium showed an increasing tendency (Table 2).

The regression models for potassium in the three cultivars exhibited high coefficients of determination ($R^2 > 0.75$), which demonstrated a stable dependence of its content in the leaves on the development stages. That trend corresponded to the studies of Marschner (2012), in which he reported that potassium was actively mobilized to the fruits in the later stages of tree development, explaining its decrease in the leaves. The high values of R^2 (0.8–1.0) indicated that the content of phosphorus in the leaves also decreased as the growing season progressed. That can be attributed to its intensive involvement in energy metabolism and nutrient transport (Mengel and Kirkby, 2001). The regression analysis of nitrogen revealed a strong dependence in the different cultivars ($R^2 > 0.98$), confirming its intensive absorption in the initial stages and its gradual depletion during the vegetation season, in line with the studies of Tagliavini et al. (2005). Although the calcium and magnesium contents increased during the growing season, the regression coefficient of Mg in 'Cresthaven' was low ($R^2 = 0.2201$), indicating greater variation in its uptake. Similar results were obtained by Saúz et al. (1992), who found that calcium accumulation was correlated with leaf maturity. There was a significant decrease in the iron content as the growing season progressed, the highest regression coefficient being reported for 'Glohaven' ($R^2 = 0.9912$). This confirmed the results reported by Montañés and Sanz (1994), which indicated that iron was redistributed in wood and fruit over time.

The results obtained from analyzing the samples collected at 60 DAFB offered significant advantages over those collected at a later stage, as they provided an early diagnosis of the nutritional status of the peach trees. Similar conclusions were drawn by Sauz et al. (1992) and Montañés and Sanz (1994), López-Muñoz and Sánchez-Muñoz (2008) for different peach cultivars.

The nutrients did not act independently of each other. Each element exhibited the highest efficiency when the other nutrients were in sufficient quantities (Stoilov, 1977).

The correlation matrices of the cultivars 'Cresthaven', 'Glohaven', and 'Redhaven' showed the relationships between the different nutrients, depending on the development stages (60, 120, and 180 DAFB), (Table 3).

Stable relationships and a well-demonstrated strong positive correlation between the elements K and Fe at 60 DAFB and 120 DAFB were established in all three studied cultivars, the correlation coefficients ranging from R=0.560 to R=0.912. The high levels of potassium facilitated the absorption of iron, resulting in a better physiological condition of the trees (Stoilov, 1979; Marschner, 2012). For the remaining relationships between the elements, the correlation dependencies varied between the cultivars, suggesting differences in their nutritional needs.

In 'Cresthaven' cv., a strong negative relationship was observed between N (180 DAFB) and K (120 DAFB), (R = -0.756); N (180 DAFB) and K (180 DAFB), (R = -0.763); Mg (60 DAFB) and K (60 DAFB), (R = -0.702); N (120 DAFB) and K (180 DAFB), (R = -0.876); N (60 DAFB) and Ca (180 DAFB), (R = -0.683). Those results confirmed the strong antagonism between nitrogen and potassium, as well as between nitrogen and calcium. The high nitrogen level at the beginning (60 DAFB) and in the middle of the vegetation season (120 DAFB) inhibited the uptake of potassium and calcium, which may negatively influence fruit quality. Magnesium and potassium showed an antagonistic relationship: high potassium content coincided with magnesium deficiency, which may affect photosynthesis and plant resistance to various stress factors (diseases, pests, drought, etc.).

In 'Glohaven' cv., in addition to the clearly expressed synergy between K and Fe (R = 0.788), a strong positive correlation between P (60 DAFB) and K (120 DAFB), (R = 0.737), was also observed. This may be explained by previous studies referring to the participation of both elements in the metabolic processes and nutrient transport (Mengel and Kirkby, 2001). An increasing trend for phosphorus and iron concentrations was observed at both 60 DAFB (R = 0.569) and 12 DAFB (R = 0.511). There was also a synergy between magnesium and calcium, but at the later stage – R = 0.537 (180 DAFB). At the same stage (180 DAFB), a strong antagonism was observed between phosphorus and iron (R = -0.829), which could be explained by the inhibition effect that phosphorus exerts on the absorption of iron. An antagonism was also observed between Ca (60 DAFB) and K (60 DAFB), R = -0.484; Ca (60 DAFB) and Fe (60 DAFB), R = -0.578; Mg (60 DAFB) and K (180 DAFB), R = -0.526.

In 'Redhaven' cv., were found very strong positive correlations between K, P, and Fe: P (60 DAFB) and Fe (60 DAFB), R = 0.961; K (120 DAFB) and P (120 DAFB), (R = 0.880); P (180 DAFB) and Fe (180 DAFB), (R = 0.719). Negative correlations (antagonism) were also observed between: N (60 DAFB) and P (60 DAFB), (R = -0.796); N (60 DAFB) and K (60 DAFB), (R = -0.774); N (120 DAFB) and Fe (120 DAFB), (R = -0.799), as the high nitrogen levels inhibit the efficient uptake of phosphorus, potassium, and iron. A high nitrogen content at the beginning and in the middle of the growing season have been reported to inhibit the absorption of these elements, potentially disturbing nutritional balance and leading to poor fruit quality (Stiles and Reid, 1991; Tagliavini et al., 2005). The antagonistic relationship between Mg (60 DAFB) and P (60 DAFB), (R = -0.575) and Mg (60 DAFB) and Fe (60 DAFB), (R = -0.527) was also clearly expressed and ~~showed~~ suggest that the high magnesium content could cause phosphorus and iron deficiency, in which case balanced nutrition is the key for optimal plant development.

4. Conclusion

The mineral composition of peach leaves varied significantly depending on the cultivar and the time of sample collection. General trends were observed, with a decrease in the contents of nitrogen, potassium, phosphorus, and iron during the vegetation season, and an increase in the levels of calcium and magnesium. The differences between cultivars indicated their specific needs.

There was a significant correlation between the time of sample collection and the concentration levels of potassium, nitrogen, phosphorus, and iron. The derived linear regression equations allowed the prediction of the content of those nutrients with a high degree of accuracy. The early dates of sample collection (60 DAFB) were particularly useful for predicting the nutritional status of the trees. Consequently, to ensure high and consistent fruit yield and quality, early-season leaf analysis is recommended over midseason or late-season diagnostics, as it allows for timely identification and correction of nutrient deficiencies.

Nutrients in the peach tree foliage did not act independently of one another, but exhibited complex synergistic and antagonistic relationships that varied depending on the plant development stage and cultivar. The most stable synergistic relationship was observed between potassium and iron at 60 and 120 DAFB in the studied cultivars. In 'Glohaven' and 'Redhaven' cultivars, a positive correlation was also observed between P and K, as well as between P and Fe. A strong antagonism was established between N/K, N/Ca, and N/Fe, especially at higher nitrogen concentrations in the early stages of tree development. Antagonism was also found between Mg/K, Mg/P, and Mg/Fe, again at the beginning of the growing season. This study offers valuable insights for optimizing peach fertilization strategies and underscores the significance of leaf nutrient concentrations and their intricate interrelationships during cultivation.

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Tables and figures

Table 1. Mineral nutrient content of the different cultivars on the 60th, 120th, and 180th days after full bloom (DAFB), average for the period 2023-2024

60 DAFB	% N	%K	%P	% Ca	%Mg	mg/kg Fe
Cresthaven	3.51 a	2.52 b	0.44 b	2.48 b	0.56 a	104.93 a
Glohaven	3.14 b	2.82 a	0.53 ab	2.89 a	0.52 a	115.71 a
Redhaven	3.16 b	3.04 a	0.58 a	2.76 a	0.47 a	113.10 a
120 DAFB	% N	%K	%P	% Ca	%Mg	mg/kg Fe
Cresthaven	2.66 a	2.51 ab	0.41 a	2.86 b	0.85 a	102.76 a
Glohaven	2.46 b	2.37 b	0.40 a	2.93 b	0.75 b	94.92 b
Redhaven	2.51 ab	2.80 a	0.43 a	3.90 a	0.78 ab	97.53 ab
180 DAFB	% N	%K	%P	% Ca	%Mg	mg/kg Fe
Cresthaven	1.66 b	1.30 b	0.27 a	3.05 b	0.82 a	85.68 ab
Glohaven	1.62 b	1.48 b	0.29 a	3.57 a	0.63 b	94.90 a
Redhaven	2.12 a	1.88 a	0.28 a	3.93 a	0.70 ab	75.91 b

Table 2. Dependencies between the time of sample collection and the content of mineral elements in three peach cultivars – equations and regression coefficients, on average, for the period 2023 – 2024

Elements	Glohaven	Redhaven	Cresthaven
K (%)	$Y = -0.0102x + 3.3301$, $R^2 = 0.756$	$Y = -0.0111x + 3.5587$, $R^2 = 0.966$	$Y = -0.0098x + 3.7418$, $R^2 = 0.896$
P (%)	$Y = -0.0025x + 0.7319$, $R^2 = 1.000$	$Y = -0.0014x + 0.501$, $R^2 = 0.800$	$Y = -0.002x + 0.6436$, $R^2 = 0.996$
N (%)	$Y = -0.0085x + 3.6121$, $R^2 = 0.982$	$Y = -0.0129x + 3.9562$, $R^2 = 0.997$	$Y = -0.0154x + 4.4624$, $R^2 = 0.998$
Ca (%)	$Y = 0.3396x + 2.4506$, $R^2 = 0.794$	$Y = 0.5828x + 2.3629$, $R^2 = 0.766$	$Y = 0.2843x + 2.0976$, $R^2 = 0.737$
Mg (%)	$Y = 0.0022x + 0.4839$, $R^2 = 0.662$	$Y = 0.0036x + 0.2864$, $R^2 = 0.939$	$Y = 0.0009x + 0.5247$, $R^2 = 0.220$
Fe (mg/kg)	$Y = -0.31x + 132.71$, $R^2 = 0.991$	$Y = -0.1734x + 122.65$, $R^2 = 0.751$	$Y = -0.1604x + 117.04$, $R^2 = 0.833$

Table 3. Correlation coefficients representing the relationships between the nutrients in the leaves of the studied cultivars at 60, 120, and 180 DAFB

Cresthaven	%K (60 DAFB)	%P	% Ca	%Mg	% N	mg/kg Fe	%K (120 DAFB)	%P	% Ca	%Mg	% N	mg/kg Fe	%K (180 DAFB)	%P	% Ca	%Mg	% N	mg/kg Fe
%K (60 DAFB)	1																	
%P	0.444	1																
% Ca	0.059	0.344	1															
%Mg	-0.702	-0.215	0.296	1														
% N	0.429	0.209	-0.297	-0.486	1													
mg/kg Fe	0.677	0.204	-0.189	-0.610	0.426	1												
%K (120 DAFB)	0.651	0.280	-0.003	-0.551	0.350	0.868	1											
%P	-0.093	0.115	-0.031	0.120	-0.262	-0.522	-0.395	1										
% Ca	-0.049	-0.045	0.263	0.112	-0.094	-0.172	-0.043	0.330	1									
%Mg	0.022	-0.042	-0.045	0.094	0.048	-0.319	-0.125	0.538	0.536	1								
% N	0.008	0.097	0.042	-0.174	0.101	0.222	0.104	-0.477	-0.515	-0.582	1							
mg/kg Fe	0.560	0.559	-0.025	-0.466	0.421	0.552	0.683	-0.087	-0.274	0.105	0.102	1						
%K (180 DAFB)	0.433	0.051	0.342	-0.066	-0.421	0.107	0.846	0.388	0.688	0.382	-0.876	0.041	1					
%P	-0.489	-0.234	0.153	0.337	-0.053	0.654	-0.106	-0.846	-0.043	-0.489	0.323	-0.387	-0.184	1				
% Ca	-0.044	0.192	0.704	0.220	-0.683	-0.072	0.649	0.017	0.757	0.186	-0.366	-0.220	0.627	0.214	1			
%Mg	-0.002	-0.093	0.145	0.043	0.264	-0.301	0.191	0.185	0.305	0.489	-0.184	0.353	0.008	-0.231	-0.042	1		
% N	-0.198	-0.021	0.053	0.291	0.071	-0.412	-0.756	-0.052	-0.322	0.002	0.731	0.065	-0.763	0.026	-0.325	0.257	1	
mg/kg Fe	-0.252	-0.234	-0.448	-0.105	-0.011	0.055	-0.065	-0.013	-0.394	-0.196	-0.113	0.263	0.033	0.027	-0.103	-0.648	-0.259	1
Redhaven	**%K (60 DAFB)**	**%P**	**% Ca**	**%Mg**	**% N**	**mg/kg Fe**	**%K (120 DAFB)**	**%P**	**% Ca**	**%Mg**	**% N**	**mg/kg Fe**	**%K (180 DAFB)**	**%P**	**% Ca**	**%Mg**	**% N**	**mg/kg Fe**
%K (60 DAFB)	1																	
%P	0.959	1																
% Ca	0.421	0.478	1															
%Mg	-0.438	-0.575	-0.538	1														
% N	-0.400	-0.437	-0.169	0.296	1													
mg/kg Fe	0.912	0.961	0.421	-0.527	-0.481	1												
%K(120 DAFB)	0.872	0.880	0.456	-0.467	-0.437	0.848	1											
%P	0.584	0.610	0.207	-0.293	-0.255	0.608	0.495	1										
% Ca	-0.158	-0.199	0.180	0.010	0.172	-0.291	0.025	-0.667	1									
%Mg	0.084	0.039	0.156	-0.079	0.148	0.039	-0.109	-0.095	0.220	1								
% N	-0.774	-0.796	-0.351	0.317	0.518	-0.799	-0.786	-0.465	0.194	-0.017	1							
mg/kg Fe	0.685	0.672	0.382	-0.446	-0.493	0.656	0.627	0.065	0.193	0.154	-0.503	1						
%K(180 DAFB)	0.052	0.032	0.151	-0.265	0.258	-0.066	-0.380	0.232	-0.202	0.357	0.350	0.165	1					
%P	-0.013	0.561	0.087	-0.398	0.564	0.030	0.043	0.182	0.066	-0.305	0.535	-0.025	0.403	1				
% Ca	-0.148	0.535	0.413	-0.523	0.262	0.074	-0.324	0.209	-0.120	-0.042	0.231	-0.120	0.658	0.779	1			
%Mg	-0.420	0.055	0.245	-0.047	-0.365	0.623	-0.588	0.310	-0.464	0.006	0.287	-0.297	0.366	0.169	0.530	1		
% N	-0.285	-0.260	-0.179	-0.170	0.003	-0.385	-0.137	0.375	-0.392	-0.347	-0.260	-0.492	0.279	0.003	0.273	0.225	1	
mg/kg Fe	0.054	0.820	0.320	-0.453	0.202	0.191	0.207	0.086	0.304	-0.247	0.111	-0.142	-0.043	0.719	0.607	0.116	-0.118	1
Glohaven	**%K (60 DAFB)**	**%P**	**% Ca**	**%Mg**	**% N**	**mg/kg Fe**	**%K (120 DAFB)**	**%P**	**% Ca**	**%Mg**	**% N**	**mg/kg Fe**	**%K (180 DAFB)**	**%P**	**% Ca**	**%Mg**	**% N**	**mg/kg Fe**
%K (60 DAFB)	1																	
%P	0.518	1																
% Ca	-0.484	-0.418	1															
%Mg	-0.104	-0.096	0.298	1														
% N	0.282	0.549	-0.349	-0.425	1													
mg/kg Fe	0.788	0.569	-0.578	-0.393	0.527	1												
%K (120 DAFB)	0.682	0.737	-0.446	-0.198	0.396	0.774	1											
%P	0.723	0.614	-0.596	-0.319	0.375	0.783	0.708	1										
% Ca	-0.280	-0.456	0.329	0.098	-0.347	-0.386	-0.357	-0.313	1									
%Mg	0.176	0.147	-0.066	-0.149	0.213	0.320	0.348	0.256	-0.145	1								
% N	0.019	0.157	-0.177	-0.159	0.193	0.034	-0.217	0.076	-0.290	-0.276	1							
mg/kg Fe	0.394	0.377	-0.319	-0.325	0.382	0.478	0.239	0.511	-0.049	-0.313	0.356	1						
%K (180 DAFB)	0.084	-0.034	-0.151	-0.526	0.197	-0.016	-0.146	0.234	0.169	-0.260	0.294	0.529	1					
%P	-0.005	-0.004	-0.228	-0.265	0.043	-0.030	-0.118	0.167	-0.297	-0.628	0.626	0.538	0.261	1				
% Ca	0.005	-0.236	0.029	-0.459	-0.112	-0.098	-0.573	0.356	0.328	-0.608	0.457	0.647	0.671	0.521	1			
%Mg	0.299	-0.020	-0.150	0.238	-0.232	0.131	-0.123	-0.500	0.537	-0.088	-0.171	0.440	-0.127	0.207	0.182	1		
% N	-0.221	-0.224	-0.113	-0.298	0.349	0.338	0.200	-0.347	0.240	0.202	-0.373	0.148	0.281	0.011	-0.011	0.299	1	
mg/kg Fe	0.214	-0.023	0.134	0.180	-0.055	0.272	0.099	-0.361	0.683	0.484	-0.558	-0.159	0.060	-0.829	-0.232	0.103	0.313	1