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The association between leaf nutrients of Raphia palm (Raphia spp.) and soil properties in Southern Nigeria using canonical correlation analyses

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Abstract

The association between leaf and soil nutrients of Raphia palm in Nigeria was studied using Canonical Correlation Analysis (CCA). The Leaf and soil nutrients examined were N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and B. The estimated canonical correlations showed that the first four pairs of canonical variates were significant ($P < 0.01$), while their canonical correlation revealed presence of high significant correlation (1.0000) between leaf and soil nutrients. The redundancy index calculated for the first four canonical variate for both the dependent variables and independent variables were equally high (13.97, 6.88, 8.49, 10.96) and (4.85, 6.18, 8.50, 5.14) respectively, showing that substantial percentage of the variance in leaf characteristics were accounted for by variability in soil properties. The canonical cross – loading used to provide meaning for the canonical variates showed that Ca, Fe, Cu, Zn and B in soil have significant effects on Ca and B of leaf for the first pair canonical variates. Similarly, K, Mg and Fe in soil have significant effects on P and K in leaf for the second pair canonical variates, while Mg, Fe, Mn, B in soil have significant effects on N, Ca, S, Mn, Zn and B of leaf in the third pair canonical variates. N, K and S of soil have significant effects on P, K, and B in leaf. These Results indicated that nutrient contents of leaf depend on the capacity of the soil to make nutrients available to plants for uptake and the ability of the plants to take up the available nutrient. This study has enabled us to eliminate possible Type 1 error permitted by the cross- product moment correlation analysis and highlight the importance of canonical correlation analysis as a statistical tool for the analyses between two sets of variable, and permitted a better understanding of the relationships between leaf and soil nutrients of the Raphia Palm in Southern Nigeria.

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Introduction

Several studies in the past have used simple correlation analysis to understand the association between leaf and soil nutrient elements. For example, Chumbley and Unwin (1982) detected significant correlation between concentration of Cd in soils and amount of Cd in plant tissues of Cabbage and Lettuce using simple correlation analyses. This simple correlation involved the estimation of the linear association between two variables. Using simple correlation analyses when more than one soil and plant character is taken for measurement involve estimating many bivariate relationships. As observed by Maringer, (2011), when the same variables in a data set are used for too many statistical tests, it increases the risk of Type 1 error – the likelihood of finding a statistical significant result when it does not exist. This will likely lead to wrong inferences such that any decision based on such conclusions will be misleading.

In a setting, where multiple observations of soil and leaf properties are collected from different locations, simple correlation analyses is inadequate to address the complex structure especially when considering correlation between two sets of variables simultaneously, determine the strength of relationships between two set of variables and also facilitates the study of their linear interrelationships. Canonical Correlation Analysis (CCA) is now commonly used to determine this kind of relationships in order to limit the risk of committing Type 1 error.

Canonical Correlation Analysis was originally developed by Hotelling in 1935 where he analyzed how arithmetic speed and arithmetic power are related to speed and reading power, Hair *et al* (1998). Since this pioneering work, the technique has received wide applications. Cankaya, *et al.* (2010) applied the method to the analysis of customers' satisfaction and future of mail – order specialty food. They considered two dependent and eight independent variables in order to establish the existence of significant relationship between the two sets of data. The result reveals a statistically significant relationship between the two sets of variables which, indicates that customer satisfaction is associated with service aspects of mail - order. More recently, Koko and Danbaba (2009) applied the technique to investigate the developmental relationship between Central and West Africa using socio – economic indicators. Their results revealed a significant relationship in similarities between the two regions in terms of their socio – economic indicators. Alabi *et al* (2014) used the method to study student's performance. Two sets of data representing cognate and core courses were used for the study. The results showed that there was slight correlation between the two sets of data. Iwara *et al* (2011) studied the interrelationships between soils and vegetative variables using canonical correlation. Their results indicated a positive association between the two sets of data. Akbas *et al* (2005) applied Canonical Correlation Analysis to estimate the relationships of egg production with age of sexual maturity, body weight and egg weight. The result showed that sexual maturity had the largest contribution to variation of the number of egg productions.

Despite the use of this technique in wide range of fields, its application to the study of leaf – soil interrelationship has received little application. This is particularly important because of the interactions between leaf and soil nutrients of plants. As noted by Ujwala (2011), crop will only absorb what is available in the soil and when one nutrient is insufficient in the soil, the first sign will reflect in the leaf of the plant and finally the yield. Therefore the nutrient status of the soil can determine the nutrient status of the plant and finally the yield. Based on this premise, this study applies canonical correlation analysis to the study of leaf – soil inter-relationship in order to aid the understanding of the interaction between leaf and soils nutrients of Raphia palm in Southern Nigeria.

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Materials and Methods

Data used for the study

The data used in this study were collected from Chemistry Division of the Nigeria Institute for Oil palm Research, NIFOR. The institute is at the central part of Ovia North East Local Government Area of Edo State. It is located on latitude 06°33′N and longitude 05°37′E and on altitude of 149.4m. This study explores the physicochemical properties of soils in over ninety (90) locations cultivated to Raphia species. These areas were sampled for soil and Raphia plant parts which were examined in the laboratory for physicochemical properties. They were cleaned, dried and milled into powders, and then were eventually made into solutions. Each solution was subjected to nutrient analysis for various elements such as Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca) Magnesium (Mg), Sulphur (S), Iron (Fe), Maganese (Mn), Copper (Cu), Zinc (Zn) and Boron (B).

Canonical Correlation Analysis

The relationships of the leaf nutrients and soil properties were investigated using Canonical Correlation Analysis (CCA). This technique focuses on the correlation between a linear combination of the variables in leaf nutrient variable set (X- set) – called Canonical variable V - and a linear combination of the variables in the soil properties variable set (Y-set) – called Canonical variable W – such that the correlation between the two Canonical variable is maximized (Gunderson and Muirhead,1997).

To obtain the maximum correlation between the two set of variables (leaf and soil properties), symbolically, given as:

$$Y = [Y_{1,}\ Y_{2,}\ \ldots\ \ Y_P] \quad and \quad X = [X_{1,}\ X_{2,}\ \ldots\ X_q],$$

where $Y = leaf\ nutrient$ and $X = soil\ properties$

Two linear combinations were designed as follows;

$V_m = \alpha_{m1}Y_1 + \alpha_{m2}Y_2 + \cdots + \alpha_{mq}Y_P$ (q = 1, 2, - - 11) ---------1

$W_m = bX_{m1} + b_{m2}X_2 + \cdots + b_{mq}X_q$ (P = 1, 2, - - 11) ---------2

Equations (1) and (2) give the new variables or canonical variates *V*m and *W*m, which are linear combination of X (leaf nutrient) and Y (soil properties)

Vm and Wm are the canonical variables and $(\alpha_{m1,}\alpha_{m2,} \ldots \alpha_{mp})$ and $(b_{m1,}b_{m2,} \ldots b_{mq})$ are the canonical coefficients.

The first pair of canonical variates is derived so as to have the highest inter- correlation between V_m and W_m. The second pair of canonical variates is then derived so that it exhibits the maximum relationships between the two sets of variables (variates) not accounted for by the first pair of variates. Successive canonical functions estimates pairs of canonical variates based on residual variance from previous canonical functions, and their respective canonical correlations (which reflects the interrelationships between the variates) becomes smaller as each additional function is extracted**.** The number of canonical variate extracted is dependent on the number of independent or dependent variables included in the analysis. In this study, since the Y and X variables sets are eleven, thus eleven canonical variates *(Vi, Wi)* were formed.

The canonical correlation between Vm and Wm is given as;

$C_m = Corr(V_m\ , W_m)$ ---3

Alibi *et al.* (2014) formally defined it as:

$$Correl(V, N) = \frac{\alpha'\sum XYb}{\sqrt{\alpha'\sum XX\alpha}\sqrt{b'\sum YYb}} \text{ -----------------------------4}$$

where:

$$Var(V) = \alpha'\sum XX\alpha$$
$$Var(W) = b'\sum YYb$$
$$CoVar(V, W) = \alpha'\sum XYb$$

The hypothesis is given as:

$$H_0 : C1 = C2 = - - - Cm = 0$$

i.e. There is no relationship between the canonical variates.

$$H_1 : C1 \neq C2 \neq - - - Cm \neq 0$$

i.e.; there is a relationship between the canonical variates.

A test of the statistical significance for canonical correlation can be done using the Wilks lambda and the Likelihood ratio tests.

The Wilks lambda is given as:

$$\lambda = \frac{/R/}{/R_{yy}//R_{xx}/} \text{ ---5}$$

where: R is the correlation between $x's\ and\ y's$
Rx is the correlation between $x's$
Ryy is the correlation between $y's$

Rejection of the H_0 hypothesis implies that at least one of the canonical correlations is statistically significant. However, the significance of the Wilk's Lambda is also equal to that of likelihood ratio test (Mendes and Akkartal, 2007). The canonical correlation coefficient measures the strength of the relationship between W_m and V_m.

The squared canonical correlation (canonical roots or eigenvalues) represents the amount of variance in one canonical variate accounted for by the other canonical variates.
Symbolically, this defined as;

$C_m^2 = Corr(V_m\ , W_m)$ ---6

To select the numbers of canonical variates to retain in the analysis, the level of statistical significance, magnitude of the canonical correlations and the redundancy index or measures were used. A most common practice is to interpret function whose canonical correlation coefficients are statistically significant beyond some levels, typically (P< 0.05) or less.
The redundancy measure on the other hand provides the amount of variance in the dependent variate explained by the independent variate, and vice versa. This can be defined as;

RI = SV X RC^2 ---7

Where RI is the redundancy index, SV is the amount of shared, which represent the correlation between the canonical variate and each of its variables while RC^2 is the amount of explained variance, which represent the squared correlation between the independent canonical variate and the dependent canonical variate

To determine the relative importance of each of the original variables in the canonical relationships, three methods have been proposed; the canonical weight (standardized coefficients), canonical loadings (structure correlations) and canonical cross – loadings.

The canonical weights approach to the interpretation of the canonical functions involves examination of the sigh and the magnitudes of the canonical weights assigned to each variable in its canonical variates. Variables with relatively larger weights contribute more to the variates, and vice versa. Similarly whose weights have opposite sighs exhibit an inverse relationship with each other, and variables with weights of the same sighs exhibit direct relationship.

Canonical loadings on the other hand have been increasingly used for the interpretation of canonical variates because of the deficiency inherent in canonical weights. The canonical loading measures the simple linear correlation between an original variable in the dependent or independent set and the set's canonical variates. The loading reflects the variance that the observed variables shares with the canonical variate. The larger the coefficients, the more important it is in deriving the canonical variate.

The canonical cross-loadings have been suggested as an alternative to canonical loadings. This procedure involves correlating each of the variables directly with the other canonical variate, and vice versa. For example, each dependent variable would be correlated separately with variates for the independent variables. Thus cross- loadings provides a more direct measure of the dependent – independent variables relationship by eliminating an intermediate step involved in conventional loadings.

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Table 1: The simple correlation analysis between leaf nutrients and soil properties

	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B	N1	P1	K1	Ca1	Mg1	S1	Fe1	MN1	Cu1	Zn1	B1
N	-	-0.1034	-0.0241	-0.19314	-0.09497	-0.01942	-0.08355	0.01109	-0.02626	-0.09563	-0.10629	-0.01513	0.12403	0.43221	-0.00969	-0.11886	-0.19436	0.25754	-0.03271	0.0288	-0.05797	0.57078
P		-	0.15169	0.09653	0.5508	0.28981	-0.26	-0.13986	0.01029	0.75015	0.10755	0.31412	-0.00534	-0.16038	-0.15138	-0.07746	0.22528	0.13193	-0.06055	-0.04668	-0.08625	-0.0627
K			-	-0.04474	0.24116	0.31111	0.20684	-0.03144	0.45669	-0.00447	0.03531	0.14591	0.42703	0.51457	-0.16685	-0.05696	0.03359	0.22448	0.14161	-0.07984	-0.26035	-0.07646
Ca				-	0.41701	0.20615	-0.38562	-0.33132	0.00241	-0.0776	0.10296	-0.25123	0.11592	-0.108	0.33653	0.32772	-0.32088	0.06025	0.00079	-0.20275	0.14153	0.22729
Mg					-	0.39669	0.32025	-0.14219	0.15431	0.20962	0.22531	0.34665	0.04457	-0.20099	-0.03003	0.09887	0.20009	0.13944	0.18217	-18554	-0.26544	0.06212
S						-	-0.05766	-0.18707	-0.04817	0.37897	0.23854	-0.02303	0.32883	0.05039	0.28502	0.05173	-0.18567	-0.09979	-0.06284	-0.16537	-0.19265	0.17574
Fe							-	0.46916	0.25306	-0.08963	0.81179	0.21262	0.25888	0.25589	-0.32271	0.1425	-0.09189	-0.02541	0.57128	0.23373	-0.29882	-0.36911
Mn								-	-0.06471	-0.10478	-0.34286	0.19584	-0.19393	-0.04728	-0.54318	-0.2183	0.05062	0.01375	0.27598	0.11104	-0.25154	-0.21479
Cu									-	0.15463	-0.14211	0.17879	0.33245	0.11216	-0.23503	0.19505	-15474	0.44786	0.22398	0.17692	-0.1654	-0.21575
Zn										-	-0.0182	0.23635	0.06879	-0.15211	-0.12061	-0.05992	0.02387	0.09287	0.00552	-0.0088	-0.0957	-0.23865
B											-	0.21434	0.27668	0.24034	0.18411	0.34956	0.2993	-0.10704	-0.13167	-0.06459	-0.12855	-0.02955
N1												-	0.36557	0.16928	-0.12183	0.40325	0.74581	0.26445	0.23583	0.21713	0.17483	0.04288
P1													-	0.61534	0.30501	0.76161	0.1057	0.4914	0.13861	0.47176	0.0634	0.27856
K1														-	0.10711	0.2223	0.05545	0.32561	0.16206	0.08735	-0.17175	0.32522
Ca1															-	0.37258	0.02372	0.12484	-0.01574	-0.05857	0.48627	0.6752
Mg1																-	0.22123	0.23757	0.12263	0.58446	0.32212	0.17016
S1																	-	0.03755	-0.08537	0.29245	0.28447	0.05686
Fe1																		-	-0.08066	0.20661	-0.22536	0.23665
MN1																			-	0.00516	-0.25214	-0.07214
Cu1																				-	0.13145	-0.03451
Zn1																					-	0.36866
B1																						-

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All computation was performed by means of the PROC CANCORR Procedure of the SAS program (SAS Institute, 2002).

Results and Discussion

Table 1 shows the correlation matrix for the leaf and soil properties. An examination of the result shows that N in leaf correlated positively with K and B of the soil properties. The implication of this is that increases in K and B in the soil increases uptake of N in the leaf. Similarly, P in leaf correlated positively with N in the soil while K in leaf was positively related to P and K in soils. Ca of leaf correlated positively with Mg but negatively with S in soil properties. Other parameters such as Mg, S and Fe of leaf also correlated positively with N, P and Mn soil properties respectively. The result also revealed that Mn, Cu and B of leaf nutrient were positively related to Ca, P, Fe and Mg of soil properties indicating that as these elements increases in the soil, there is a corresponding increase in Mn, Cu and B uptake in the leaf.

The cross-product moment correlation gives information only on the relationship between two variables without considering simultaneously other variables that are related with each other. Estimating simple correlation in relationships between two data sets of variables may increase the risk of Type 1 error – the likelihood of finding a statistical significant result when it does not exist. Therefore, canonical correlation analysis was used to investigate these relationships and aid the interpretation.

Table 2 shows the result of the canonical correlation analysis of the eleven canonical variates, their corresponding squared canonical correlations, eigen values, likelihood ratio and their probability levels. Four of the canonical correlation were significant ($P < 0.000, 0.000, 0.001, 0.001$) respectively, meaning that four out of the eleven canonical correlation were significantly different from zero. The canonical correlations and the proportion of variance common to the first canonical variate pair (V1, W1) was 100%. Similarly, correlation coefficients and the proportion of variance common to the other canonical variates pairs (V2, W2), (V3, W3) and (V4, W4) respectively was also 100 percent. This shows that high significant relationships exist between leaf and soil nutrients. However, since a large canonical correlation does not always mean that there is a powerful relationship between the two sets of variables, redundancy index which provides the amount of variance in the dependent variate (leaf nutrient) explained by the independent variate (soil properties), and vice versa was further used to determine the number of canonical variate or function to retain in the analysis.

Table 2: Canonical correlations coefficients of leaf nutrients and soil properties

Canonical function	Canonical correlation	Squared canonical correlation	Degree of freedom	Eigenvalues	Likelihood ratios	Probabilities
1	1.00000	1.00000	121	Infinity	0.00000	0.0000
2	1.00000	1.00000	100	Infinity	0.00000	0.0000
3	1.00000	1.00000	81	Infinity	0.00000	0.0001
4	1.00000	1.00000	64	Infinity	0.00000	0.0001
5	0.96274	0.92687	49	12.6738	0.00619	0.9944
6	0.86515	0.74849	36	2.9761	0.08476	0.9995
7	0.60207	0.36249	25	0.5686	0.33704	0.9999
8	0.55729	0.31058	16	0.4505	0.52869	0.9989
9	0.41189	0.16966	9	0.2043	0.76686	0.9954
10	0.24934	0.06217	4	0.0663	0.92355	0.9720
11	0.12339	0.01522	1	0.0155	0.98477	0.7578

A redundancy index is calculated for the independent and dependent variates for the first four functions, Table 3. As stated by Mendes and Akkartal, (2007), a redundancy index of .484 is substantial, this means that the redundancy index for both the dependent variables and independent variables as presented above is highly substantial. Therefore the first four functions should be accepted, while the other seven insignificant canonical functions are therefore disregarded for further interpretation. The table shows that the first variate explains 4.85 percent of the variance in the soil variables (independent variables) while the second variate explains 6.18 percent. The third and fourth variate explains 8.50 and 5.14 percent respectively. Together, the four canonical variates explain about 24.67 % of the variance in the soil vwariables. For the leaf nutrients (dependent variables), 13.97, 6.88, 8.49 and 10.96 respectively were explain by the first, second, third and fourth canonical variates. The total variance accounted for by the four canonical variate was about 40 percent. The table also shows the amount of variance of the independent variables explained by the dependent variables for the four functions as; 4.85%, 6.18%, 8.50% and 5.14% respectively which cumulatively accounted for 24.67% of the variance of the independent variables explained by the dependent variables. This means that, the amount of variance of the soil properties explained by the leaf nutrients cumulatively as 24.67%. Also, the amount of the variance of the dependent variables explained by the independent variables for the four functions are, 13.97%, 6.88%, 8.49% and 10.96% respectively which cumulatively accounted for 40.3% of the variance of the leaf nutrients explained by the soil properties for the four functions . This finding confirms the reciprocal relationship existing between leaf nutrients and soil properties of the raphia palm. The implication of this result is that the plant takes more nutrients from the soil than it releases back to the soils.

Table 3: Redundancy measures (RM)

Canonical variates	Dependent variables (leaf)	Independent variables (soils)
V1W1	13.97	4.85
V2W2	6.88	6.18
V3W3	8.49	8.50
V4W4	10.96	5.14

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Table 4 shows the standard canonical coefficients (canonical weights). The magnitudes of the canonical coefficients signify their relative contributions to the correlated variates. As suggested by Tabachnic and Fidell (2001), correlation coefficients between the original variables and canonical variates (loadings) in excess of 0.300 are interpreted. The first canonical variate (V1) for the Y variables set (leaf nutrients) contains large positive loadings of (Ca, B) and relative large negative loadings of (Fe, Zn). The first canonical variate for the X variables set (soil properties) contains (N, K, Ca, Fe, Cu) negative loadings and (P, Mg, S, B) positive loadings. The second canonical variates, for V1 (P, S, Cu,) contains negative loading while (K, Ca, and Zn) contains positive loadings. P, K, S, Mn, Cu, Zn, B were more important in forming W2. For the third pair canonical variates (Mg, S, Fe, Cu, Zn) and (P, K Ca, Mg, S, Mn, Cu, Zn, B) contains large loadings for V3 and W3 respectively. For fourth canonical variates pairs (N, K, S) contains large positive values for V4 while N,P, Mg, S, Fe, Mn, Zn and B are the more important soil properties in W4. Cumulatively for the four components, all the nutrients present in the soil make important contribution to the canonical variates while all the nutrients present in the leaf equally made important contributions except Mn. This suggests that almost all the nutrient available in the soil are taken in sufficient quantity by the plant. However, as suggested by Akbas *et al* (2005) the weights obtained are typically unstable because of the problem of multicollinearity and therefore the use of canonical weights for interpretation has been seriously criticized. Since loading provides substantial meaning for the canonical variates, emphasis on the interpretation of leaf nutrient and soil properties relationships will be restricted to the loadings and cross- loadings.

Table 4: Standardized canonical coefficients between the four canonical variates and original variates

Variables	V1	V2	V3	V4	W1	W2	W3	W4
N	0.0057	0.1136	-0.0002	**0.3305**	**-1.9751**	**-1.1316**	-0.1116	**0.5517**
P	0.0505	**-0.9129**	**-0.6361**	0.0091	**0.4133**	**0.4893**	**0.4507**	**1.5455**
K	0.0971	**1.2797**	0.1972	**0.3519**	**-0.3374**	**0.7552**	**-0.4812**	-0.2549
Ca	**0.4306**	**0.4593**	-0.0639	-0.2215	**-1.3882**	**-0.4637**	**-0.6802**	-0.0315
Mg	-0.0191	-0.0858	**1.2318**	-0.2156	**1.6482**	0.0267	**0.6046**	**-0.9919**
S	-0.0063	**-0.9591**	**-0.4661**	**0.8165**	**1.5973**	**0.7856**	**0.6656**	**-0.3192**
Fe	**-0.3548**	0.2023	**0.5951**	-0.1140	**-0.3603**	0.2936	**-0.3340**	**-0.9032**
Mn	0.1122	-0.0967	0.1545	0.0627	0.1035	**0.5024**	**0.4388**	**-0.5333**
Cu	-0.2369	**-0.5962**	**-0.3756**	-0.1071	**-1.3404**	**-0.5739**	**-0.6269**	0.0088
Zn	**-0.5222**	**1.0619**	**0.6165**	-0.0660	-0.1970	**0.7261**	**-0.6512**	**-0.5672**
B	**0.4649**	0.2628	0.2673	0.1651	**1.1215**	**-0.6219**	**0.3614**	**0.5251**

The canonical loading measure the simple linear correlation between an original variable in the dependent or independent set and the set's canonical variate, Table 5. The larger the coefficients, the more important it is in deriving the canonical variate. Thus the first canonical variate (V1) for the Y (Leaf nutrients) variable set contains relatively large positive loadings of Ca and B and relatively large negative loadings Fe, Cu and Zn. The first canonical variate (W1) for the X (soil properties) set contains higher positive values of Ca and B and formed the greater values of W1. The canonical variates V2 have higher positive values of K and Fe forming its greater values while P and K formed the greater value of W2. For V3 and W3, V3 contains relatively positive large values of Mg, Fe, Mn and B while W3, have N, S and Mn with positive large loading and Zn, B and Ca with negatively large loadings. V4 and W4 have positive large loadings of N, K, S for V4 and P, K and B for W4 respectively. However, as observed by Akbas *et al* (2005) canonical loading like weights may be subject to considerable variability from one sample to another. This variability suggest that loadings and hence the relationships ascribed to them, may be sample – specific, resulting from chance or extraneous factors. Also, when using only canonical loading for interpretation, the risk increases that the application is closer to a univariate setting than multivariate one.

Table 5: Canonical loading between the four canonical variates and original variables

Variables	V1	V2	V3	V4	W1	W2	W3	W4
N	-0.0408	-0.1016	-0.2194	0.3711	-0.2043	-0.0000	0.5755	-0.0000
P	-0.1707	-0.2226	0.2379	0.1443	-0.0108	0.3182	0.0974	0.3883
K	-0.0876	0.5760	0.0184	0.4889	0.0698	0.6644	0.0126	0.4364
Ca	0.6083	-0.0442	-0.0184	-0.1768	0.3776	-0.1449	-0.3408	0.1676
Mg	0.2651	-0.3409	0.6365	0.1088	0.1988	0.0359	0.1495	-0.0995
S	0.0436	-0.2668	0.1387	0.8054	0.0743	0.0016	0.3229	-0.0960
Fe	-0.4633	0.3186	0.3882	0.0464	-0.1400	0.1045	0.0221	-0.0276
Mn	-0.2925	-0.0365	0.3178	-0.0909	-0.2811	0.2044	0.5868	-0.1462
Cu	-0.4377	0.1942	0.1182	-0.0947	-0.2305	-0.0702	-0.0575	-0.1178
Zn	-0.5502	-0.1616	0.0925	0.1732	0.1444	-0.0614	-0.4907	-0.2219
B	0.5123	0.0979	0.3619	0.2603	0.3571	-0.2317	-0.3221	0.3035

The canonical cross- loading is said to provide a more direct measure of the dependent – independent variable relationship. It involves correlating each dependent variables directly with the variate for the independent variables, vice versa Table 6. An examination of the first canonical function for the leaf nutrient elements and soil properties shows that Ca and B for the leaf nutrient elements and Ca, Fe, Cu, Zn and B for the soil properties had score above 0.30 which is an acceptable minimum loading value. This implies that Ca and B of the leaf nutrient elements were positively related to Ca and B of soil properties and negatively

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related to Fe, Cu and Zn of soils. This means that an increase in Ca and B in the soil would result in a corresponding increase in Ca and B in the leaf. The inverse relationships between Ca and B in leaf of Raphia and Fe, Cu, and Zn properties mean that a decrease of the Fe, Cu and Zn in the soil would lead to increase of Ca and B in the leaf. The second linear combination of leaf nutrient elements and soil properties shows that a positive loading of P and K, for the leaf nutrients and a significant loading of K, Mg and Fe in the soil variate. This mean that an increase an increase in K and Fe in the soil would result in a corresponding increase in P and K, while a decrease in Mg in the soil would result in an increase in P and K . The relationship between the third canonical variates shows that N, Ca, S, Mn, Zn, B of leaf nutrient elements correlated with Mg, Fe, Mn, B of soil properties . This implies that increase in Mg, Fe, Mn, B in the soil can increase the amount of N, S, and Mn and decrease the amount of Ca, Zn and B in the leaf. Finally, P, K, B had a significant cross –loading with the dependent variables (leaf nutrient) with the fourth axis while N, K, S, soil properties were also significant. The implication of these results is that N, Ca, S, in the soil will lead to a corresponding increase in P, K and B in the leaf. These results confirmed the synergism and antagonism effects between nutrients. In some case, we see more than one nutrients working together to create an overall improved physiological state in plant and in some other cases, the excess of some nutrients reduce the uptake of other nutrients. Secondly, the results also show that the leaf not only absorbed what was available in the soil but also released some nutrients back to the soils. These findings aggress with Ujwala, (2011) conclusions, that interrelationships between nutrients in the plant system are interdependent and so is the plant nutrient status dependent on the available soil nutrients.

Table 6: Canonical cross-loading between the four canonical variates and original variables

Variable	V1	V2	V3	V4	W1	W2	W3	W4
N	-0.2043	-0.0000	0.5755	0.0000	-0.0408	-0.1016	-0.2194	0.3711
P	-0.0108	0.3182	0.0974	0.3883	-0.1707	-0.2226	0.2379	0.1443
K	0.0698	0.6644	0.0126	0.4364	-0.0876	0.5760	0.2091	0.4889
Ca	0.3776	-0.1449	-0.3408	0.1676	0.6083	-0.0442	-0.0184	-0.1768
Mg	0.1988	0.0359	0.1495	-0.0995	0.2651	-0.3409	0.6365	0.1088
S	0.0743	0.0016	0.3229	-0.0960	0.0436	-0.2668	0.1387	0.8054
Fe	0.1400	0.1045	0.0221	-0.0276	-0.4633	0.3186	0.3882	0.0464
Mn	-0.2811	0.2044	0.5868	-0.1462	-0.2925	-0.0365	0.3178	-0.0909
Cu	-0.2305	-0.0702	-0.0575	-0.1178	-0.4377	0.1942	0.1182	-0.0947
Zn	0.1444	-0.0614	-0.4907	-0.2219	-0.5502	-0.1616	0.0925	0.1732
B	0.3571	-0.2317	-0.3221	0.3035	0.5123	0.0979	0.3619	0.2603

Conclusion

In this study, the relationships between leaf and soil nutrients were studied. Since cross- product moment correlation gives information only on the relationship between two variables without considering simultaneously other variables that are related with each other, Canonical correlation was applied. The result of the canonical correlation revealed that high significant correlation (100%) between leaf and soil nutrients exist. The redundancy index computed were quite substantial indicating that soil properties have the ability to explain variation in the leaf variables and vice versa. The standardized canonical coefficients used to measure the importance of each nutrient element in the canonical variates revealed that all variables used in the study made substantial contributions to their respective canonical variates.

The cross – loading used to provides meaning for the canonical variates shows that (Ca, Fe, Cu, Zn B) in soil have significant effects on (Ca, B) of leaf. Similarly, (K, Mg, Fe) in soil have significant effects on (P, K) in leaf. Also, (Mg, Fe, Mn, B) in soil have significant effects on (N, Ca, S, Mn, Zn, and B) of leaf. Finally (N, K, S) of soil have significant effects on (P, K, and B) in leaf of Raphia palm. This show that instead just relationship between two variables, we can explain the magnitude and direction of more than one nutrients in the leaf and vice versa, thus demonstrating the usefulness of canonical correlation analysis as a better statistical tool for simplifying relationships between two sets of variables.

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