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Statistical Modeling of Heavy Metals Uptake by C*apiscum Annum* and H*abiscus Esculentus* Vegetable Crops from Irrigation Soil

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Abstract: *Multiple linear regression models have been employed as a technique for establishing possible factors affecting metal uptake and for predicting metal concentrations in plants. The aim of the research is to develop regression models for metal uptake by Habiscus esculentus and Capiscum annum from irrigation soil. Soil organic matter (OM), pH, and Cation exchange capacity (CEC) were also determined to investigate their possible influences on the metal uptake by the vegetables. Soil, Habiscus esculentus and Capiscum annum vegetable crops samples were collected from an irrigation farmland along the bank of Mada River during dry season. Heavy metal contents in the samples were quantified using atomic absorption spectrometry (AAS). Empirical multiple linear regression models developed using SSPS v. 20 software indicated soil contents to be the most dominant factor influencing metals in Habiscus annum and Capiscum annum. pH was a major factor. CEC also influenced metal uptake. High R^2 values for the regression equations of the metals, except for cu (47%) in Capiscum annum, and Fe (33%) and Mn (33%) in Habiscus esculentus, suggested that the regression models explained the dependent variable well, and the relationships were significant. The metals regression models may be used to predict their uptake from irrigated soil by the vegetable crops.*

Keywords: *Statistics, Model, Heavy metal, Capiscum annum, Habiscus esculentus, Soil, Irrigation, Farmland*

1. INTRODUCTION

Metals have a very complex chemical behaviour in the environment [1, 2], and unlike organic compounds, are not subject to degradation processes [3, 4]. Metals in agricultural soils may be mobilized to be absorbed by plants [5]. Metal bioavailability depends on several factors, including soil pH, CEC and OM content [6-8].

Relationships for metal uptake by crops from agricultural soils can be established using statistical models. An empirical model is a formal expression of a theory, or associative relationship between variables use to fit an equation or a set of equations to data. After being built up with available data, models may be used for predicting the values taken by the response variable for new data points that are not yet in the original set (predictive modelling) [9].

The relationship between dependent and independent variables for simple and multilinear regressions can be hypothesized using equations.

For simple regression model:

$$Y = \alpha + \beta X + \varepsilon$$

where Y is the dependent variable, X is the independent variable, β is the coefficient or estimate of change on X (measures how much Y changes. when X is increased by 1); and ε is the value of Y predicted to change when all the independent variables are assigned to be equal to zero; while generalized equation for multiple regression can be written as

$$Y = \alpha + \beta X + \beta_1 X_1 + \text{-----}\ \beta_i X_j + \varepsilon$$

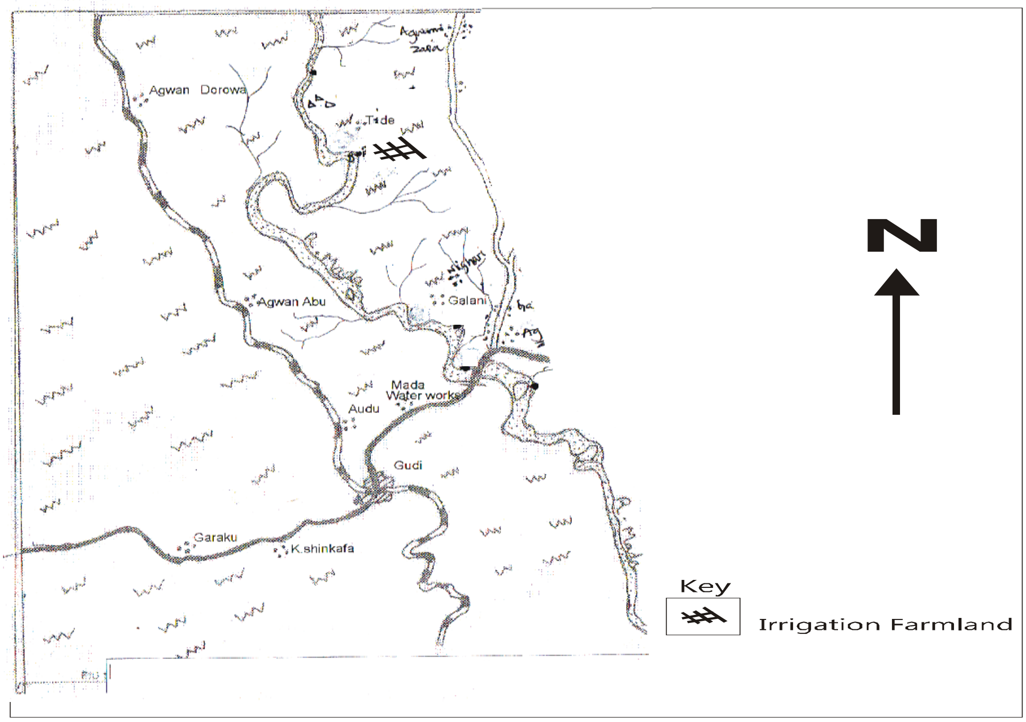
β_1 and β_i are the estimates for the independent variables X_1 and X_j respectively [10].

Empirical multiple linear regression equations have been employed as a technique for establishing possible factors affecting metal uptake and for predicting metal concentrations in plants [10,11]. Information on using multiple linear regression equations for metal contents in plants and in irrigation soil along the bank of Mada River are scarce.The aim of the research is to develop regression models of metal uptake by *Habiscus esculentus* and *Capiscum annum* from irrigation soil. Soil OM, pH, and CEC were also determined to investigate their possible influences on the metal uptake by the vegetables.

2. Materials and Methods

2.1. Study Area

The irrigation farmland measuring about a hectare is located along the bank of Mada River (Fig. 1). Mada river is located at latitude 8^{o} 4´ N and longitude 8^{o} 30´E [2]. There are high deposits of organic matter on the farm as a result of flood, especially during rainy season. Irrigation farming activities have been going on in the farm for several years.



2.2. Sampling

2.2.1. Vegetables

Twenty pepper and okra crops each were randomly collected from the irrigation farmland, washed with de-ionized water to remove extraneous materials. The roots part were cut off from each of the crop type and sliced into nearly uniform size to facilitate drying at the same rate, and combined to form a composite sample. The sample was dried in oven at 105^{o}C for 24 hours [13]. The dried sample was grind into fine particles in an acid washed mortar and pestle and then preserved in sealed plastic containers for chemical analysis.

2.2.2. Soil

Twenty sub-soil samples collected simultaneously with vegetable crops from the irrigated farmlands at a depth of 1-10cmctors [14] into clean polyethylene bags, using a hand trowel. The sub-soil samples were combined to form a homogenized composite sample. Soil samples were homogenized and air dried for seven days. The dried samples were grind in a clean mortar and pestle and sieved to pass through a 2mm alumina mesh, then preserved in washed clean plastic bottles for chemical analysis [14, 15].

2.3. pH, OM and CEC Determinations

Soil pH, CEC and OM content were determined according to methods reported by Tukura et al. (2013)

2.4. Samples Digestion

2.4.1. Vegetables

5.00g of fine particles of vegetables was measured into 100cm^3 beaker. 5cm^3 of conc. HNO_3 and 2cm^3 of conc. $HClO_4$ were added and digested at 70^{o}C for 15 minutes on a hot plate until a light coloured solution was obtained. The sample solution was cooled and then filtered into 50cm^3 volumetric flasks and made to mark with distilled water and preserved for further analysis.

2.4.2. Soil

28cm^3 37% HCl:70% HNO_3 (3:1 v/v) was added to 1.00g of the dried sieved (2mm) soil sample and left to stand for 24 hours. The mixture was then heated on a hot plate at 140^{o}C to near dryness. The residue was filtered through Whatman No. 41. The solution was then transferred into 50cm^3 volumetric flask and made to mark with distilled water then preserved for metal analysis.

2.5. Statistical Analysis

Multiple linear regression analysis was done using statistical software SPSS v.20 to develop models. Metal concentrations in different parts of crops are not a simple and direct function of the metal content soil metal content. Experimental work has suggested that soil physico-chemical properties and crop physiological functions affect the metal uptake and transport of crop [16,17]. The effects of these were investigated using multiple linear regressions models. The dependent variables in this study were the respective metal concentrations in the roots of th vegetable crops, and the independent variables were the soil metal concentrations, pH, OM content and CEC.

Assumptions were made when developing the models:

1. Soil moisture was not limited to ensure continuous uptake through transpiration.
2. The driving force for the uptake was atmospheric evaporability, which is the pertinent atmospheric factor that controls evaporation was not limiting.
3. Direct leaf absorption and diffusion from the atmosphere were not considered.
4. Initial soil metal concentration was negligible and that metal uptake was from irrigation water.
5. Soil solution available trace metals to the crop for uptake was equal to the stabilized irrigation water metal concentration applied

3. Results and Discussion

Soil pH (6.48 ± 0.10), OM (14.08 ± 0.10%) and CEC (6.50 ± 0.03 cmol/kg) have been reported [18]. Heavy metal concentrations in irrigation soil and roots of *Hibiscus esculentus* and *Capiscum annum* are presented in Table 1. Metal levels varied according to vegetable type.

Empirical multiple linear regression equations for metal concentrations in soil and in the roots of *Habiscus esculentus* and *Capiscum annum* are presented in Table 2 and Table 3 respectively.

Table 1. *Metal concentrations (mg/kg) in irrigation soil and roots of vegetable crops*

Metals	Soil	*Capiscum anum*	*Habiscus esculentus*
Cd	0.100	0.006	0.003
Cr	0.050	0.140	0.090
Cu	0.049	0.050	0.050
Pb	0.090	0.050	0.040
Zn	0.242	0.260	0.270
Ni	0.068	0.100	ND
Fe	5.950	2.810	2.300

Table 2. *Multiple linear regression equation for metal concentrations in soil and roots of Habiscus esculentus*

Metals	Regression equation	R^2 (%)	SE
Cd	$Cd = -0.036 + 0.087\ Cd_s + 0.005\ pH$	82	0.001
Cr	$Cr = -0.039 - 0.037\ Cr_s + 0.037\ pH + 0.005\ OM + 0.016\ CEC$	96	0.015
Cu	$Cu = -0.008 + 0.006\ Cu_s + 0.002\ pH$	81	0.000
Pb	$Pb = 1.985 - 0.173\ Pb_s - 0.254\ pH - 0.018\ OM\ \ 0.044\ CEC$	57	0.153
Zn	$Zn = 0.256 - 0.010\ Zn_s + 0.003\ pH + 0.001 CEC$	85	0.002
Fe	$Fe = 2.419 + 0.007\ Fe_s - 0.020\ pH - 0.001\ OM - 0.004\ CEC$	39	0.326
Mn	$Mn = 0.189 - 0.003\ Mn_s + 0.006\ pH + 0.001\ OM$	39	0.005
Ni	$Ni = -0.003 - 0.014\ Ni_s + 0.001\ pH$	70	0.000

OM: Organic matter; CEC: Cation exchange capacity; SE: Standard error

Table 3. *Multiple linear regression equation for metal concentrations in soil and roots of Capiscum anum*

Metals	Regression equation	R^2 (%)	SE
Cd	$Cd = 0.007 + 0.019\ Cd_s - 0.001 pH$	80	0.001
Cr	$Cr = 0.459 - 8.540\ Cr_s + 0.013\ pH + 0.001\ OM - 0.005 CEC$	100	0.004
Cu	$Cu = -0.370 - 0.039\ Cu_s + 0.049\ pH + 0.016\ CEC$	47	0.063
Pb	$Pb = 0.160 - 2.130\ Pb_s - 0.011\ pH - 0.110\ OM + 0.065\ CEC$	87	0.034
Zn	$Zn = 0.022 + 0.046\ Zn_s + 0.078\ pH + 0.008\ OM - 0.049\ CEC$	98	0.034
Fe	$Fe = 4.492 + 0.045\ Fe_s + 0.405\ pH + 0.050\ OM - 0.277\ CEC$	94	0.143
Mn	$Mn = -1.817 + 0.392\ Mn_s + 0.038\ pH + 0.003\ OM - 0.019\ CEC$	100	0.012
Ni	$Ni = 3.348 - 3.831 Ni_s - 0.423\ pH + 0.020\ OM - 0.082 CEC$	96	0.087

OM: Organic matter; CEC: Cation exchange capacity; SE: Standard error

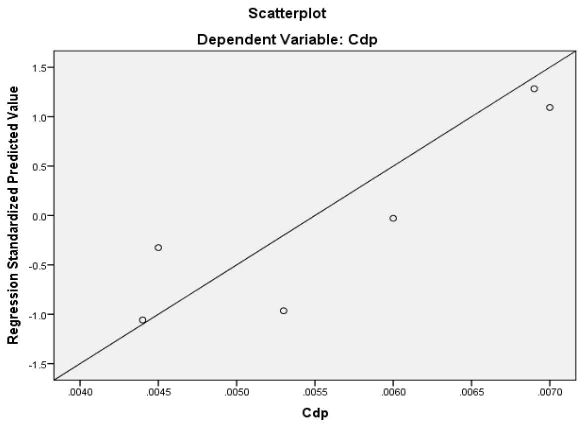
Regression analysis allows for the determination of relationship between two or more variables, and to predict a depended variable using one or more independent variables [10]. For regression with multiple independent variables, the coefficient tells of how much the dependent variable is expected to increase or decrease when the independent variable increases by one, keeping all other independent variable constant [19]. There is a combination of factors affecting metal uptake by plants. Stepwise linear multiple regression method was applied to find the dominant factors influencing metal uptake by plants. The first independent variable was always total metal content in surface soils[17].

Results in Table 2 indicated that Cd, Cu and Fe contents in the roots of *Habiscus esculentus* and soil related positively. Soil pH contributed positively to metal levels in the vegetable, except for Pb and Fe. CEC and OM contents in soil might not influenced Cd, Cu and Ni levels in *Habiscus esculentus*.

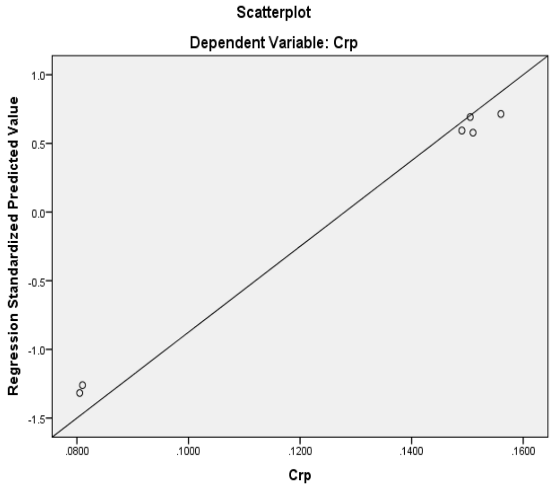
At every stage, the significance of the equation was tested by the coefficient of determination (R^2) and probability (p). If the equation was not significant (low r-squared value or high probability), other factors were used to obtain the best fit regression equation for predicting metal concentrations in plants [10, 20]. R^2 statistic is a measure of the extent to which the total variation of the independent variable is explained by the regression. Low value of R^2 may indicate that important and systematic factors have been omitted [21]. R^2 values (Table 2) revealed that soil Cd, Zn, and Ni contents explained the variability of the metal in *Habiscus esculentus* to the extent of 82%, 96%, 85% and 70% respectively, and indicated a significant relationship (p = .05).

Regression models in Table 3 indicated inverse relationships for metal contents in soil and *Capiscum annum*, except for Cd, Zn and Mn. pH and metal contents in the vegetable related negatively for Cd, Pb and Ni. This suggests that an increase in soil pH may lead to a decrease in metal uptake. OM contributed positively to the concentrations of metals, except for the negative relationship with Pb and no influence on Cd. Metal contents in *Capsicum annum* and soil CEC related negatively, except for Cu and Pb. High R^2 values (80 – 100%) for the regression equations of the metals, except for Cu (47%), suggested that the regression model explained the dependent variable well, and the relationship is significant. The metals regression models may be used to predict their uptake from irrigated soils. Low value of R^2 for Fe (33%) and Mn (39%) in *Habiscus esculentus* and Cu (47%) in *Capsicum annum* indicated that important and systematic factors have been omitted [21]. Positive or negative relationships for metal contents in the vegetables and soil pH, CEC and OM contents suggested that change in these factors may affect metal uptake. Predicted plots in Fig. 2 and Fig. 3 showed that the empirical multiple linear regression equations can be used to predict metal uptake by the roots of *Capiscum annum* and *Habiscus esculentus* respectively.

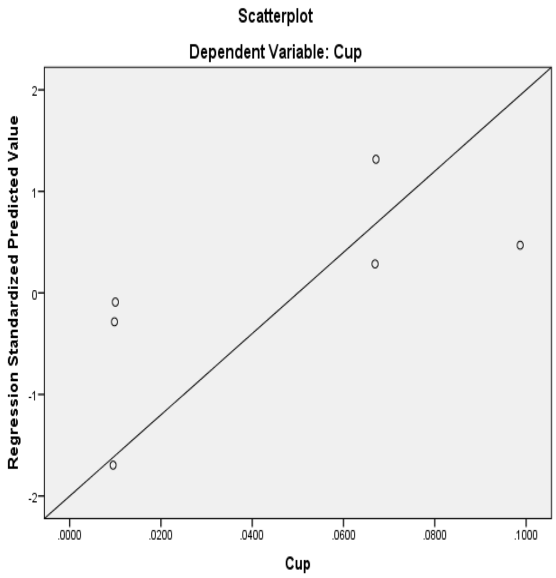
Empirical multiple linear regression equations establishing the relationships for soil pH and Cd in the vegetable crops in this study agrees with the regression equation reported for red pepper and spring onions, and Pb in soya beans [11] and in Spring wheat [17].



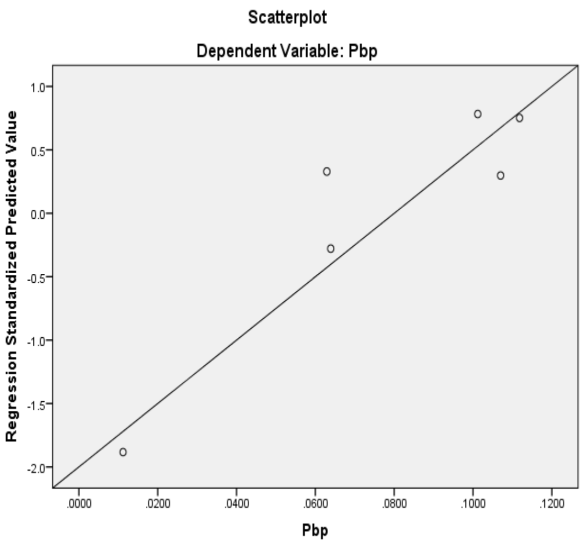
(a) Cd



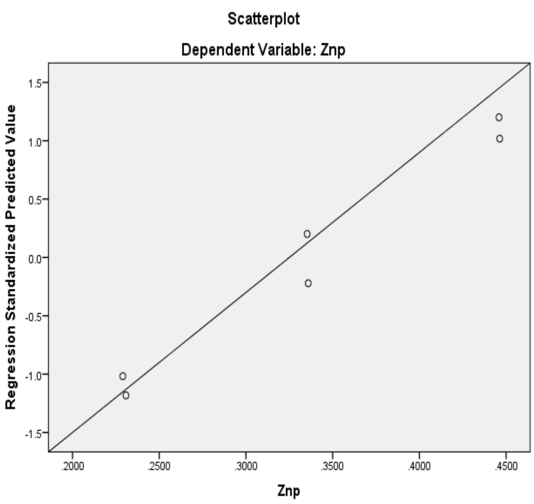
(b) Cr

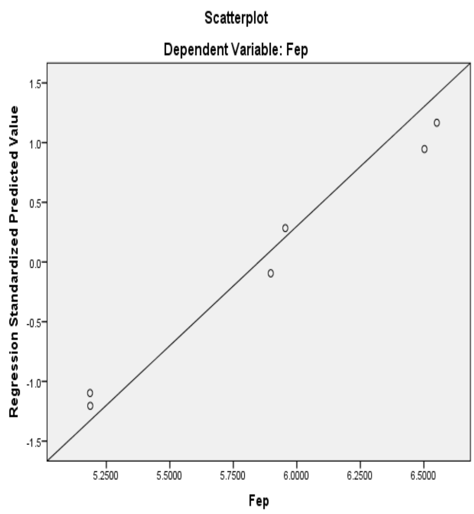


(c) Cu

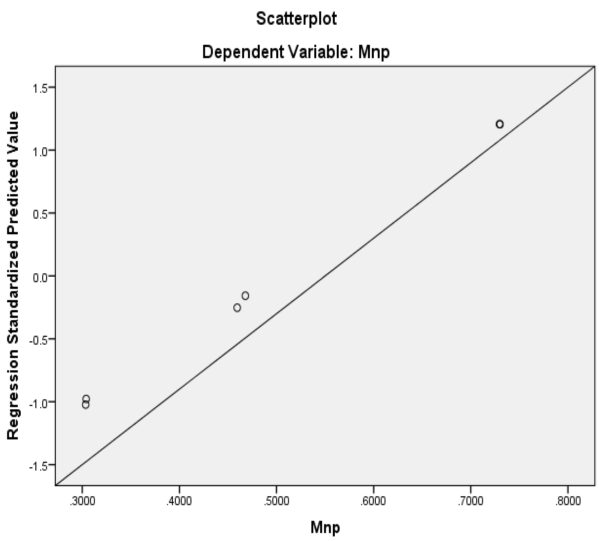


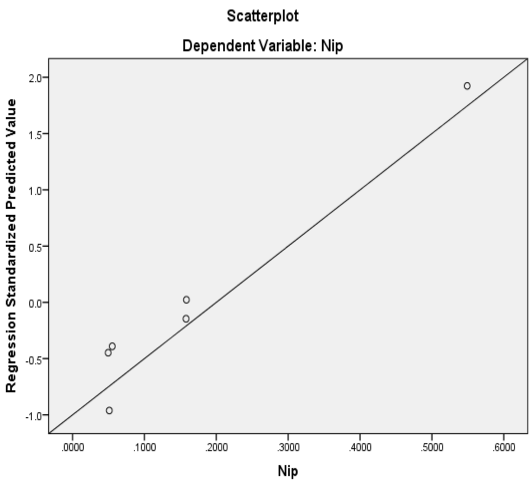
(d) Pb





(e) Zn (f) Fe



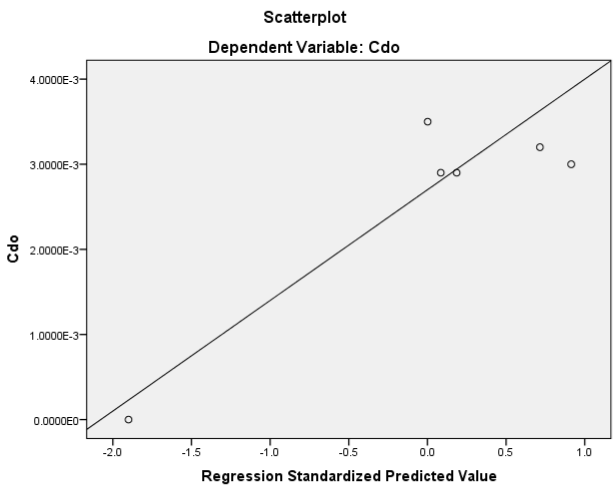


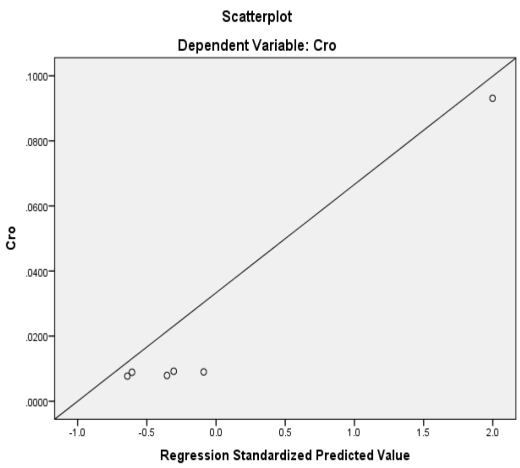
(g) Mn

(h) Ni

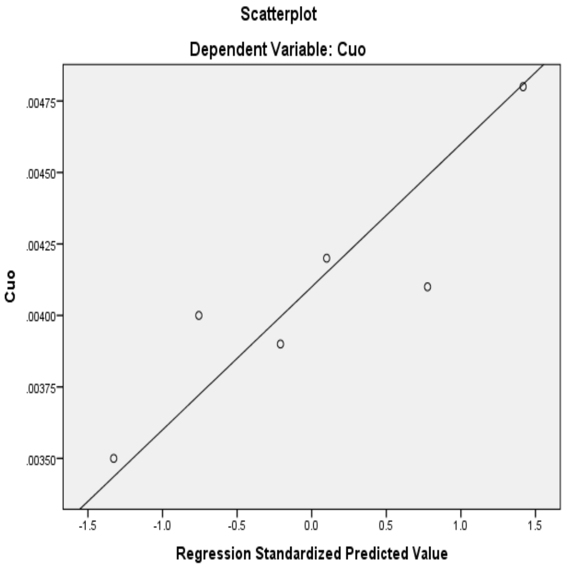
Fig.2 *Predicted levels of metals uptake in Capiscum annum vegetable*

(a)

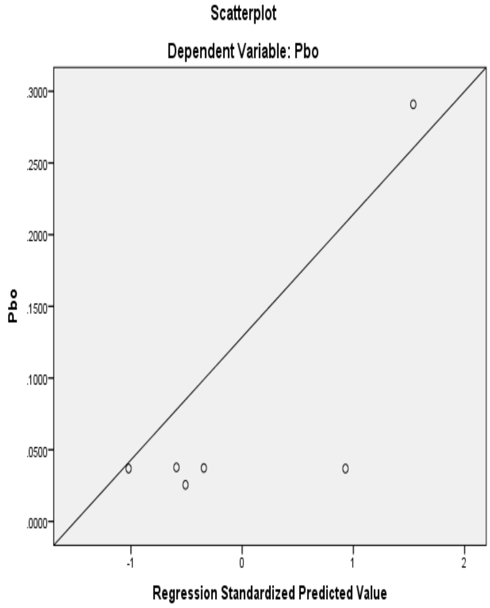




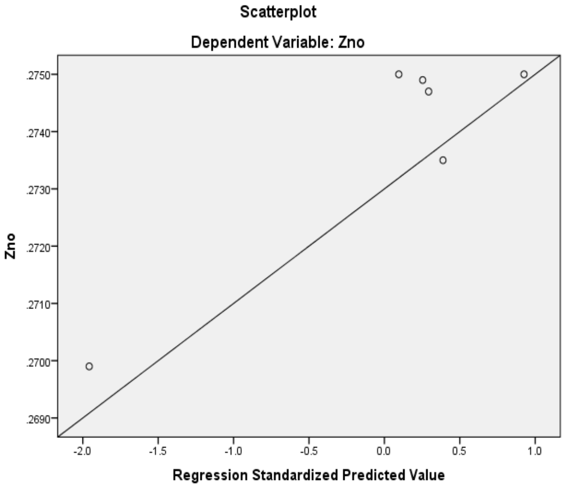
(a)Cd (b) Cr



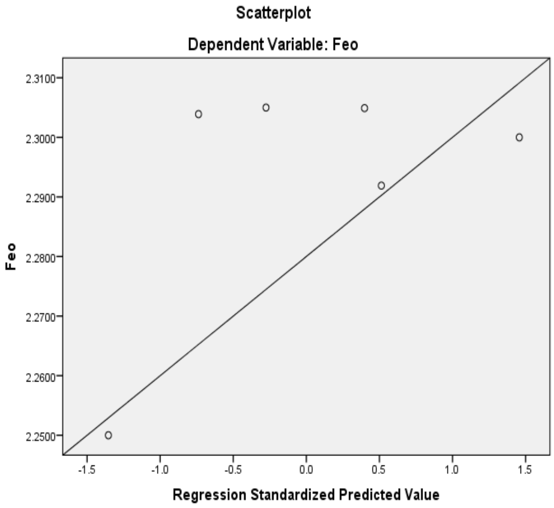
(c)Cu



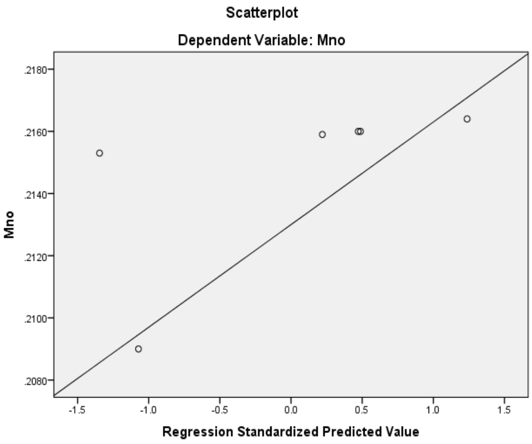
(d) Pb



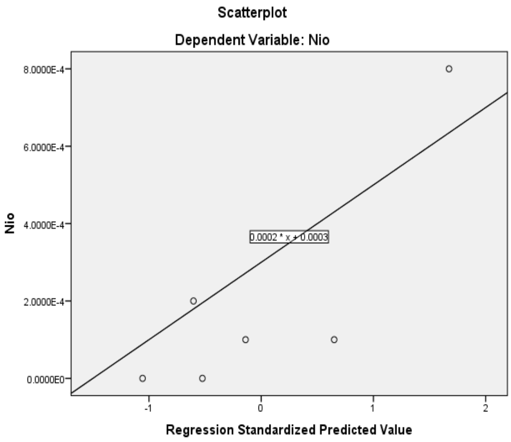
(e)Zn



(f) Fe



(g) Mn



(h) Ni

Fig 3. *Predicted levels of metals uptake in Habiscus esculentus*

4. CONCLUSION

Empirical multiple linear regression analysis indicated soil contents to be the most dominant factor influencing metals in *Habiscus annum* and *Cpiscum annum*. pH was a major factor. CEC also influenced metal uptake. High R^2 values for the regression equations of the metals, except for Cu (47%) in *Capiscum annum,* and Fe (33%) and Mn (33%) in *Habiscus esculentus* suggested that the regression model explained the dependent variable well, and the relationship is significant. The metals regression models may be used to predict their uptake from irrigated soils.

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Lecturing for 16yrs, with many publications in international and local journals. Have attended many conferences, both local and International. Areas of interest include Analytical Chemistry, Environmental Chemistry and Food Chemistry. Married with children. Love writing and listening to Christian music. Appreciate people who are willing to assist others grow academically.