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CORRELATION ANALYSIS OF NUTRIENT SOIL-PLANT CONTENT AND BUD TAKE SUCCESS IN *Hevea brasiliensis* MUELL. ARG. IN ACIDIC SOIL OF SOUTH EASTERN NIGERIA

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ABSTRACT

Numerical analysis of some quantitative nutrient soil-plant content and bud take in *Hevea brasiliensis* (HB) were carried out in 2014 and 2015 at Rubber Research Institute of Nigeria Sub-station Akwete, Abia State, Nigeria. Further, effect of different fertilizer doses and bud wood age on soil - plant nutrient absorption and *Hevea* budding success was also investigated during this study. Three doses of N.P.K (20:10:10) fertilizer (0, 100, and 150 kg/ha) were applied to five bud wood garden of different ages (2, 5, 10, 15 and 20 years) in a factorial pattern with three replicates in late October 2014. Budding activities and transplanting were carried out in 2015. Result of study revealed that bud wood age and NPK fertilizer significantly ($P < 0.05$) increased bud stick length, bud take percentage and sprouting. Significant positive correlations ($P < 0.01$) were reported between soil calcium and magnesium, soil organic matter and total nitrogen, available phosphorous, exchangeable potassium; leaf nitrogen, calcium and phosphorous contents. Percentage bud take showed positive effect with soil organic carbon, total nitrogen, exchangeable calcium, leaf calcium and nitrogen content. Four Principal components (PC) had eigen values greater than one and contributed 99.6 % of the total variation among the studied parameters. PC1 contributed 69.30%, whereas PC2, PC3 and PC4 contributed 14.84 %, 9.11 % and 6.35

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% respectively of the total variation. Accordingly, PC1 was loaded with soil organic carbon, total nitrogen, available phosphorous, exchangeable potassium, calcium, magnesium, leaf nitrogen and calcium contents and were most discriminative. Hence, appropriate selection based on PC1 parameters will enhance *Hevea brasiliensis* budding programme in southeastern Nigeria.

1 Introduction

Natural rubber (*Hevea brasiliensis*) is an important plantation crop that is grown in over 10.3 million hectares globally (International Rubber Study Group, 2012). Along with its ecological importance, rubber is mainly grown in the humid tropical areas of Nigeria where the soil is highly weathered, characterized by rapid organic matter decomposition (Awodun et al., 2007) Strongly acid with low exchangeable base cations and available phosphorous (P) as well as high iron (Fe) and manganese (Mn) concentration (Waizah et al., 2011; Oku et al., 2012; Suchartgul et al., 2012). Soil is a reservoir of plant nutrients and greatly varies with their distribution in time and space due to changes in chemical and physical characteristics (Awe et al., 2007). The productivity depends on the equilibrium between organic input supply and decomposition. Plant growth and development depend largely on the combination and concentration of mineral nutrients available in the soil and this is greatly influenced by root adaptations. For plants to maintain nutrient homeostasis, nutrient uptake and respond to changes in the soil and within the plant must be regulated (Kumar et al., 2017). Essential nutrients for plant growth could either be from organic or inorganic source or their combination. The inorganic sources involved the use of fertilizers. However, organic amendments decompose very rapidly under hot and warm humid tropical conditions and require repeatedly application at short intervals to sustain soil productivity (Jenkinson & Ayanaba, 1977; Dharmakeerthi et al., 2012).To improve and obtain sustainable *Hevea* bud stick and latex yield, proper management of essential nutrients is required. Soil and plant nutrient content analysis have often been used for nutrient diagnosis based on the hypothesis that there is relationships between plant growth rates (yield) and its nutrient content (Marschner, 1997).

Soil nutrient management with inorganic fertilizer or integrated nutrient application in rubber supporting soils in terms of improved vigour and establishment, latex yield, dry rubber content of latex and soil nutrient conservation have been reported (Okore et al., 2007; Esekhade et al., 2013; Abraham et al., 2015; Alle et al., 2015; Okore et al., 2016). Previously conducted studies revealed significant effects of organic manure on the growth and nutrient cycling of *Hevea* (Tolentino, 2010; Waizah et al., 2011; Dharmakeerthi et al., 2012; Damrongrak et al., 2015).

Various researchers have utilized various available numerical analysis methods like multivariate technique; Cluster Analysis (CA), Discriminant Analysis (DA) , Principal component analysis (PCA) for characterizing distinct agronomic characteristics and soil relationships in various crops such as rubber (Alika, 1991; Gouvêa et al., 2010; Omokhafe & Alika,2000), rice (Nassir, 2002; Adebisi et al., 2013), melon (Idehen et al., 2007), wheat (Habibpour et al., 2012), African yam bean (Nwofia et al., 2014) and in soil properties characterization (Nageswara & Jose, 2002; Campbell, 2004; Couto et al., 2006; Iwara et al., 2011; Edokpayi et al., 2015).

Principal Component Analysis is a method that reduces data, exhibits the association between two or more parameters of a crop dividing the total variance of the original parameters into limited number of uncorrelated new variables. The reduction leads to linear transformation of the original variables into a new set of noncorrelated variables, known as Principal Components (PCs) (Wiley, 1981). The analysis also helps to identify the genetic distance between crop genotypes (Aremu et al., 2007). PCs are orthogonal and independent of each other revealing different properties of the original data as may be interpreted independently. According to Mohammadi & Prasanna (2003), total variation of the original data could be partitioned into components that are cumulative in nature. The purpose of this study is to investigate the effect of fertilizer and bud wood age on bud take of *Hevea brasiliensis* as well as assess their effects on the soil and leaf nutrient contents of the crop.

2 Materials and Methods

The field experiment was conducted between 2014 and 2015 *Hevea brasiliensis* bud wood garden cut back and budding seasons at the Rubber Research Institute of Nigeria Substation Akwete, Abia State (lat. 4° 50' and 4° 65´N and Long.70 00' and 70 19' E). The climate is humid tropics with an average precipitation of 2,163 mm. The temperature is generally high ranging from 33-34°C as the maximum and 28 - 29°C as the minimum. It has two distinct seasons (rainy season- March / April to October and dry season- November to March). The soils of Akwete are mainly coastal plain acid sands of Niger Delta Basin derived from unconsolidated sedimentary deposits of Miocene Pleistocene periods (ILACO- NEDECO, 1966; Kamalu et al., 2014).

The treatments comprised a 5 X 3 factorial combinations arranged in a randomized complete block design with three replications. The first factor consisted of five bud wood garden of different ages (2, 5, 10, 15 and 20 years) while the second factor consisted of three doses of NPK 20:10:10 fertilizer (NPK) (0, 100 and 150 kg/ha). The fertilizer was applied in late October 2014 after cutting back the bud woods, while budding was carried out in 2015. The budded stumps were transplanted to the field at 0.5m x 0.5m spacing. All the standard agronomic practices for bud wood garden establishment and management were adopted.

Composite soil (0 - 15cm depth) and plant tissues were collected from each treatment in three replicates for chemical properties. Prior to analyses, soil samples were air-dried, grounded to pass through a 2 mm sieve and analyzed for soil pH with a digital pH meter in distilled water at soil / water (1:1). Bray P-1 extractant was used to extract available P and measured by the Murphy blue coloration and determined on a spectronic 20 at 882um.Exchangeable Potassium (K^+), Magnesium (Mg^{2+}), and Calcium (Ca^{2+}) were extracted with neutral normal ammonium acetate. K^+, Ca^{2+} were determined by flame photometer while $Mg^{2+}$was by atomic absorption spectrophotometer. Soil organic carbon (SOC) was determined by wet oxidation method and total nitrogen (TN) by the micro-kjeldahl techniques (AOAC, 1990). The leaf tissues were prepared by washing, oven dried for 48 hours at 70^0C and milled. The tissues were analyzed for N content using micro – Kjeldahl method and the P, Ca, Mg and K contents determined using wet oxidation method (IITA,1979). Parameters such as bud stick length (cm), percentage bud take and sprouting were collected manually by physical counting.

The data generated were subjected to Principal component analysis (PCA) according to PRINCOMP procedure using SAS software (SAS, 1996) to identify parameters that could improve budding of *H. brasiliensis*. Pearson correlations were determined to examine inter- character relationships among the parameters using the SPSS version 16.0 (2004) following the procedure outlined by Miller et al., (1958). The degree of significance of the correlation coefficients of the parameters was tested according to the standard table (Snedecor & Cochran, 1980).

3 Results and Discussion

The study revealed that bud wood ages and fertilizer doses significantly (P < 0.05) influenced the produced bud stick length (Table 1). Among the various NPK application dose, 100kg/ha of NPK fertilizer significantly produced the longest bud stick (166.33 cm) as compared to the other doses. Further, in case of bud wood garden age, bud sticks produced from 15 year bud wood garden were longer (199.96 cm) but statistically not different with bud stick obtained from 10 year old bud wood

(166.69 cm). The interaction between the bud wood garden and fertilizer doses was not significant.

Application of 150 kg/ha NPK fertilizer significantly (P < 0.05) increased the percentage bud take (68.78 %) (Table 2). This value was higher than 0 and 100 kg/ha NPK fertilizer doses by 23.11 % and 17.41 %, respectively. 10-year old bud wood significantly recorded the highest percentage bud take (72.22 %). While lowest percentage bud take of 53.49 %, 54.67 % and 55.51 % were obtained with 2, 5 and 20 years bud wood, respectively. The interaction of bud wood ages and NPK fertilizer doses on percentage bud take were significant and the highest value of 81.82 % was observed with the application of 150kg/ha NPK fertilizer on 5 years bud wood garden.

Contrary to percentage bud take, % sprouting was not significantly (P > 0.05) affected by NPKF doses, with 100 kg/ha

Table 1 Effect of *H. brasiliensis* bud wood garden age and NPK fertilizer doses on bud stick length (cm)

BA (Years)	FD doses (kg/ha)			
	0	100	150	Mean
2	110.67	173.33	145.33	143.12
5	123.00	158.30	140.00	140.43
10	212.00	150.33	137.40	166.59
15	155.83	165.38	188.67	199.96
20	121.67	184.33	131.64	147.55
Mean	144.64	166.33	149.61	

LSD (0.05): BA = 45.06, FD = 20.71, BA x FD = NS, BA = Bud wood age, FD = Fertilizer dose, BA x FD = Bud wood age and fertilizer doses interaction

Table 2 Effect of bud wood garden age and NPK fertilizer doses on percentage bud take and percentage sprouting of H. *brasiliensis*

BA (Years)	FD doses (kg/ha)							
	Percentage Bud take (28 DAB)				Percentage sprouting (90 DAT)			
	0	100	150	Mean	0	100	150	Mean
2	53.35	53.55	53.77	53.49	61.70	58.30	41.70	53.90
5	32.24	50.00	81.82	54.67	68.30	66.70	50.00	61.70
10	66.67	70.00	80.00	72.22	75.00	83.30	75.00	77.80
15	49.67	60.00	75.00	61.56	25.00	50.00	33.30	36.10
20	62.50	50.70	53.33	55.51	58.30	33.30	25.00	38.90
Mean	52.80	56.81	68.78		57.70	58.30	45.00	

LSD (0.05): BA = 0.4562, FD = 0.3534, BA x FD =DAB = 0.7902; BA = 19.87, FD = NS, BA x FD =NS, DAB = Days after budding, DAT = Days after transplanting.

NPKF giving the highest number of percentage sprouted budded stumps (P > 0.05). This value was 1.03 % and 22.8 % higher than those of 0 and 150 kg/ha of NPKF respectively. 10 year old bud wood garden produced the highest percentage sprouting value of 77.8 % relative to other bud wood ages. The general increase in bud stick length and % bud take with corresponding increase in bud wood age revealed the effect of root length in nutrient absorption. This is however in contrast to the reports of Ishfaq et al. (2012) in sweet orange and Samish & Gur (1962) in avocado with different rootstock ages.

Combined Pearson's correlation analysis of soil and leaf nutrient parameters (Table 3) showed that except leaf potassium that showed negative and non-significant (P > 0.05) relationship with leaf calcium; soil pH, soil organic carbon, total nitrogen, available phosphorous, exchangeable potassium, calcium, magnesium, leaf nitrogen; leaf phosphorous had positively higher significant (P <0.01) relationship with leaf calcium. Soil pH, soil organic carbon, total nitrogen, available phosphorus, exchangeable potassium, calcium and magnesium showed a highly positive significant (P < 0.01) correlation with leaf nitrogen. Similar positive relationship were reported by Kumar et al. (2017) in mustard. Leaf potassium exhibited negative and non – significant (P > 0.05) correlation with soil pH, total nitrogen, available phosphorous, K^+ and Ca^{2+} and leaf nitrogen.

Similarly, leaf magnesium was negatively correlated with soil organic carbon (r = -.305), total nitrogen (r = -.425), available phosphorous (r = - .220), K^+ (= - .194), Ca^{2+} (r = -.286), Mg^{2+} (r = -.323), leaf nitrogen (r = -.349) and leaf potassium (r = -.240). Furthermore, soil pH had a significantly positive (P < 0.01) correlation with soil organic carbon (r = .970), total nitrogen (r = .961), available phosphorous (r = .945) and the exchangeable bases measured; leaf phosphorous (r = .737), leaf calcium (r = .810) except leaf potassium and leaf magnesium. Mg^{2+} and Ca^{2+} were highly significant (P = 0.01) and positively correlated with soil organic carbon (r = .989), total nitrogen (r = .978), available phosphorous (r = .979), K^+ (r = .978), Ca^{2+} (r = .990) and soil organic carbon (r = .985), soil nitrogen (.976), soil phosphorous (r = .956), K^+ (r = .967) respectively.

Significant and positive relationship existed between soil potassium and soil phosphorous with soil organic carbon (r = .989), soil nitrogen (r = .951), soil phosphorous (r = .994) and soil organic carbon (r = .981), soil nitrogen (r = .941) respectively. The significant and positive correlation between soil phosphorous and soil organic carbon (r = .980**) indicates that the availability of soil phosphorous is influenced by the content of organic carbon and soil pH (Kavitha & Sujatha, 2015). The strong positive and significant correlation observed amongst soil parameters corroborates previous works by Corley & Tinker (2009); Kavitha & Sujatha (2015), Abraham et al. (2015) in their reports on soil fertility evaluation. Also, Osayande et al. (2014) observed numerous interactions where one ion or nutrient interferes with or competes with the uptake and utilization of other nutrient by plants due to dynamics in soil pH. The strong relation between

Table3 Combined Pearson's correlation between soil and leaf chemical properties across the bud wood ages

	SpH	SOC	TN	AvP	SK	SCa	SMg	LN	LP	LK	LCa	LMg
SpH	1											
SOC	.970**	1										
TN	.961**	.980**	1									
AvP	.945**	.980*	.941**	1								
SK	.965**	.981**	.951**	.994**	1							
SCa	.970**	.985**	.976**	.956**	.967**	1						
SMg	.959**	.989**	.978**	.979**	.978**	.990**	1					
LN	.966**	.990**	986**	.963**	.969**	.996**	.996**	1				
LP	.737ns	.821**	-.828**	.860**	.812**	.777**	.852**	.822**	1			
LK	-.420ns	.333ns	-.313ns	-.212ns	-.308ns	-.372ns	.252ns	-.316ns	.251ns	1		
LCa	.810**	.859**	.919**	.785**	.785**	.858**	.867**	.867**	.822**	-.176ns	1	
LMg	-.232	-.305ns	-.425ns	-.220ns	-.194ns	-.286ns	-.323ns	-.349ns	-.550*	-.240ns	-.732**	1

**, significant at 1 % level; *, significant at 5 % level; ns, non-significant; SpH, Soil pH; SOC, Soil organic carbon; TN, Total nitrogen; AvP, Available phosphorous; SK, Exchangeable potassium; SCa, Exchangeable calcium; SMg, Exchangeable magnesium; LN, Leaf nitrogen; LP, Leaf phosphorous; LK, Leaf potassium; LCa, Leaf calcium; LMg, Leaf magnesium.

potassium and organic carbon of the soil is line with the reports of Chauhan (2001) and Kavitha & Sujatha (2015). According to Kamalu et al. (2014) major problem associated with acidity of soils is the conversion (fixation) of added nutrients to unavailable forms. Furthermore, Tisdale et al. (1993) reported that decomposition of organic matter produces humus, which protects phosphorus against fixation. Percent Bud take with leaf nutrient and soil contents relationship as presented in Table 4 indicates that percent bud take had a positive association (P > 0.05) with leaf nitrogen (r = .279) and leaf calcium (r = .544*) and negatively significant (P = 0.05) associated with leaf potassium (r = -.532) and leaf magnesium (r = -.586). The result further indicated that % bud take had positive but non-significant (P > 0.05) relationship with soil potential of hydrogen, soil organic carbon, total nitrogen, available phosphorous and the exchangeable bases (potassium, calcium and magnesium).This demonstrates the importance of these nutrient in actualizing substantial success in the production of certified *Hevea* planting materials as reported by Okore et al. (2007).

Table 4 Pearson's correlation between leaf, soil nutrient parameters and bud take in *H. brasiliensis*

Parameters	R	Parameters	R
% BT	1	BT	1
LN	.279	SpH	.255
LP	-.018	SOC	.216
LK	-.532*	SN	.336
LCa	.544*	SP	.029
LMg	-.586*	SK	.087
		SCa	.281
		SMg	.197

*R = Correlation coefficients, * = Significant at 5% level of probability*

The principal component analysis (PCA) (Table 5) showed the relationship between the 13 studied parameters and their latent root values as a basis of identification of variation and classification. Accordingly, coefficients equal to or greater than 0.3 have large effect to be considered important (Raji, 2002). While parameters having less than 0.2 coefficient value are considered to be of no effect to the over-all variation as observed in this study (Idehen et al., 2007; Yada et al., 2010).

The PCA grouped the parameters to orthogonal components with the first four groups having eigen values greater than unity and together accounting for 99.6% of the total variability; with PC1, PC2, PC3 and PC4 contributing 69.30, 14.84, 9.11 and 6.35 % respectively of the total percentage variability. This signifies the nutrients influence on budding performance. The most contributing parameters to bud take success in PC1were soil pH (0.26), soil organic carbon (0.27), total nitrogen (0.27), available phosphorous (0.27), exchangeable potassium (0.27), calcium (0.27) and magnesium (0.28) and leaf nitrogen (0.27). Similar results were obtained by Edokpayi et al. (2015) in describing the nutrient status of soils supporting oil palm in southern Nigeria. While in PC2, contributions were manifested through leaf calcium (0.28). In PC3, the most important parameters to percent bud-take (budding success) were leaf phosphorus (-0.41), leaf potassium (-0.65) and leaf magnesium and leaf potassium (- 0.24) in PC4

Table 5 Principal component analysis of soil and leaf chemical parameters and bud take in *H. brasiliensis* grown on acid sand soil

Parameters	PC1	PC2	PC3	PC4
% B T	0.05150	0.55477	0.18132	-0.18137
SpH	0.26344	0.04394	0.10919	0.16168
SOC	0.26921	0.04213	0.01777	0.17667
TN	0.26695	0.11648	-0.01555	0.10256
AVP	0.26748	-0.06442	-0.03468	0.18990
K+	0.26658	-0.03608	0.03016	0.21769
Ca^{+2}	0.27259	0.05119	0.08020	0.04137
Mg^{+2}	0.27462	0.01782	-0.01380	0.05885
LN	0.27328	0.06368	0.01972	0.05556
LP	0.23214	-0.02276	-0.40483	0.06095
LK	-0.06605	-0.21513	-0.65281	-0.24420
LCa	0.23444	0.28057	-0.17536	-0.00360
LMg	-0.08266	-0.21513	-0.65281	0.10324
Latent roots	13.166	2.820	1.730	1.207
Percentage variation	69.30	14.84	9.11	6.35
Cumulative %	69.30	84.14	93.25	99.6

Conclusion

The study showed that fertilizer application and bud wood garden age significantly increased the bud stick length and % bud take. Soil organic carbon was positively and highly correlated with soil nitrogen, phosphorous, potassium, calcium, magnesium, leaf nitrogen and leaf calcium. These parameters as further identified in PC1, have potentials in enhancing budding programme in *Hevea* multiplication. Consequently, soil nutrient management should be of utmost importance for successful annual production of certified *Hevea brasiliensis* budding materials, irrespective of the bud wood garden age.

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Conflict of interest

The authors have no conflict of interest in the course of this study.

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