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Nutritive Value And Nutrient Uptake Of Aloe Vera L. Burm F. Grown In Beach Sand As Influenced By Nutrient Application

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Abstract: *This study was conducted to investigate the optimum combination of nutrient for enhanced yield and nutrient composition for Aloe vera. The study consists of 72 pot trial, each containing 2 kg washed beach sand, the effect of nutrient application on the nutritive value and nutrient uptake by Aloe vera plant was determined at 6 months after transplanting. Missing nutrient experiment of 18 treatments comprising macronutrient, micronutrient and their combinations was laid out in a completely randomized design. Data on Leaf Length (LL), Leaf Width (LW), Leaf Thickness (LT), Leaf Volume (LV), Number of Suckers (NS), Number of Leaves (NL), Weight Gain (WG), Plant Dry Matter (PDM), Nutrient Uptake (NU), Nutritive Value (NV) and proximate composition were measured and analysed using descriptive statistics and ANOVA at p = 0.05. In the missing nutrient experiment, LL, LW, LT, NS, NV, NU, protein and fat were lowest for treatments without N, P and K indicating that these were the most critical macronutrients. It was concluded that to achieve maximum nutrient composition, uptake and nutritive value of Aloe vera, external source of nitrogen, phosphorus and potassium will be necessary.*

Keywords: *Aloe vera, Beach sand, nutrient application, nutritive value, proximate composition*

I. Introduction

Aloe vera L. Burm f. is a semi tropical medicinal plant with curative and regenerative properties [1] Historical evidence points Africa as the center of origin; people in the Mediterranean have a long history of association with the crop [2]. *Aloe vera* is ranked high as an all-purpose herbal plant [3]. There are about 23, 600 hectares under Aloe (*Aloe vera* and other species) cultivation worldwide, with 19,100 hectares located in the Americas. About 10,700, 3,500 and 3,400 hectares are cultivated in Mexico, Dominican Republic and Venezuela respectively, with areas under cultivation expanding at a fast rate [4a]. The size of the industry for Aloe raw material is estimated at about 125 million US dollars while the volume of the industry for the finished products is about 110 billion US dollars ([4b]; [5]; [6]). *Aloe vera* represents an interesting commercial and economic resource for export, job creation and raising of national income [7]. The trade is controlled largely by the USA [5]. In Nigeria, *Aloe vera* is commercially grown for the local market [6]There is a shift from routinely evaluating the plant for medicinal purpose only. Research efforts are now geared towards evaluating the chemical composition and nutritive value of *Aloe vera* and other tropical medicinal plants [8]. Phytochemical studies have shown the presence of several bioactive compounds that originated from primary and secondary metabolic pathways in *Aloe vera* plants, and these have been widely used in the commercial formulations of gels and juices. Some of the compounds include enzymes (lipases, bradykinases and proteases), monopolysaccarides (glucomannans), amino acids, vitamins (A, B_{12}, C and D), anthraquinones (aloine and emodine), saponins, salicylic acid, lignin and steroids (lupeol, campesterol and sitosterol). Some of the biological activities that have been ascribed to these substances include antiseptic (saponins and anthraquinones), anti-tumor (mucopolysaccharides), anti-inflammatory (steroids and salicylic acid), antioxidant (vitamins) and immune regulator effects (glucomannans) [9]. Due to the wide spectrum of application in human health, the products containing *Aloe vera* compound are increasing in demand at both national and international markets. Like any other plant, *Aloe vera* requires essential nutrients for growth and development. Adequate and proper balance of plant nutrients is essential for rapid growth and maximum yield of crops [10]. Most tropical soils, including Nigerian soils, are inherently low in soil organic matter and fertility, which makes external fertilizer application imperative for raising crop productivity [11]. With the recent drive towards the multipurpose use of *Aloe vera* in Nigeria, the judicious use of production inputs, like fertilizers for optimum yield deserves critical investigation in order to determine an optimum combination of nutrients for growth and productivity of the plant. In India, the general recommendation is 15 tonnes /ha of farmyard manure per year and 50:50:50 kg NPK / ha as basal dose [12]. There is paucity of information on the effects of fertilizer application on *Aloe vera* in tropical environments. The objective of this study is to determine the effect of nutrient application on the nutritive value, proximate and nutrient uptake of *Aloe vera.*

II. Materials and methods

The study was carried out in the screenhouse of the Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso, Oyo State (Latitude 8° 10'N and Longitude 4° 25'E) in the Derived savannah agro-ecological zone of Southwestern Nigeria.

2.1 Soil sampling, preparation and laboratory analysis:

Beach sand was collected from Lagos Lagoon, sieved through 2mm mesh and washed several times with water to leach out the nutrients. It was sun-dried and subjected to laboratory analysis before use. Representative sample was taken and air–dried, crushed and sieved through 2mm for the determination of particle size, pH (H_2O), available P, extractable micronutrient (Fe, Cu, Mn, Zn) and exchangeable cations (K, Mg, Ca, Na). Soil sieved through 0.5mm mesh was used for both the determination of total nitrogen (N) and organic carbon. Particle size analysis was carried out according to [13] hydrometer method using sodium hexametaphosphate as the dispersant. Soil pH was determined in 1:1 soil water ratio ([14]; [15]). Total N was extracted by the macro–Kjeldahl digestion method [16] followed by colorimetric determination using Technicon Autoanalyser [17]. Melich 3 (a multipurpose extractant) was used to extract available phosphorus, exchangeable cations (Ca, Mg, K and Na) and extractable micronutrients (Mn, Fe, Cu and Zn) [18]. Phosphorus was determined colorimetrically using the Technicon AAII Auto-analyser, while the concentration of (Calcium, Magnesium, copper, Zinc, Iron and Manganese) in the extract were determined by Atomic Absorption Spectophotometer (AAS) (Model Buck 200A). Sodium (Na) and K were determined using Flame emission photometer. Exchangeable acidity was determined by KCl extraction method [19]. Effective cation exchange capacity (ECEC) was determined by summation of Exchangeable bases (Ca, Mg, K and Na) and Exchangeable acidity. Organic carbon was determined by chromic acid digestion method [20].

2.2 Determination of the effects of nutrient application on the nutritive value, proximate composition and uptake of *Aloe vera.*

A missing nutrient experiment ([21] [22]; [23]) was carried out in the screenhouse with washed beach sand. The washed beach sand ensures that it is only the nutrient fed to the plants that it feeds on. This authenticates any observation(s) made because it eliminates biofactors which are the reservoir of nutrient elements in arable soils. Likewise, the symptoms of deficient or missing nutrient can be easily detected. A transparent plastic pot containing 2 kg sand was placed on another white plastic pot that has the nutrient solution. A wick was used to convey water containing nutrient from below to the sand because sand is not able to retain water. There were 18 treatments each replicated four times to give a total of 72 experimental units arranged in a completely randomized design. Two months old suckers collected from the Department of Agronomy, University of Ibadan, Ibadan were weighed before planting in each of the transparent plastic containing 2 kg sand.

2.3 Nutrient application for the growth of *Aloe vera*

Macronutrient and micronutrient elements were added to the washed beach sand in solution form prepared from analytical grade chemicals. The nutrient under investigation was omitted in each set. The sand was watered to field moisture capacity and left for 48 hours to equilibrate. The investigation consisted of 18 treatments of complete nutrient (N, P, K, Ca, Mg, S, Cu, Zn, Fe, Mn, Bo and Mo) compared with eleven with one each of the nutrient missing and five of missing nutrient combinations of N and P, N and K, P and K, N, P and K as well as deionised water (control). Modified Jensen's solution method [24] was used to prepare stock solutions for the nutrient solutions. The complete nutrient treatment was prepared from two solutions viz A and B. Solution A was prepared by dissolving in one litre of distilled water the following: 10g $CaHPO_4$, 2g K_2HPO_4, 2g $MgSO_4.7H_2O$, 2g NaCl, 1g $FeCl_3$ and 0.25g KNO_3. For the preparation of solution B, the following were dissolved in one litre of distilled water: 2.86g H_3BO_3, 1.81g $MnCl.4H_2O$, 0.22g, $ZnSO_4.7H_2O$. 0.08g $CuSO_4.5H_2O$ and 0.025g $Na_2MoO_4.2H_20$. 10mls of solution B was pipetted into 10 litres of solution A, autoclaved and allowed to cool. Other solutions were prepared by removing the missing nutrients before preparing the stock solutions. The solutions of the nutrients were added two weeks after transplanting.

The shoots and roots harvested were freeze-dried at -50^0C with a freeze dryer to a constant weight for dry weight determination of the total biomass yield and to determine the nutrient concentration. Deficiency symptoms noticed were recorded.

2.4 Data analysis

Data collected were subjected to analysis of Variance (ANOVA) [25]. Treatment means were separated using Duncan's Multiple Range Test at 5% probability level.

III. Results

3.1 Physical and chemical characteristics of the experimental soil

The pH for the beach sand and Ogbomoso location was near neutral and slightly acidic respectively (Table 1). The organic carbon for the field was about 240% higher than that of the beach sand. Similarly, available P and total N were higher in field site by 233 and 422% respectively compared to that of beach sand. The beach sand contains 930, 20 and 50 g kg^{-1} sand, silt and clay respectively while the corresponding values for Ogbomoso experimental site soil was 870, 40 and 90 g kg^{-1}. The soil textures of the samples from the beach and Ogbomoso location were sand and loamy sand respectively.

3.2 Effect of missing nutrients on nutritive value, proximate composition and nutrient uptake of *Aloe vera* grown in beach sand

3.2.1 Nutritive value and proximate composition

All proximate composition values were significantly ($P \leq 0.05$) affected by missing nutrients (Table 4.2). Highest protein content was obtained when K was absent but was not significantly different ($P \leq 0.05$) from the value obtained when Ca was absent. The least protein content was obtained when B was absent and this was also not significantly different from when Cu and NPK were absent. The protein content of complete nutrient, though significantly higher than some other treatments, was significantly lower compared to that of K and Ca. Overall, the protein content value range from 1.3 to 4.6 %. The least fat content was obtained when Mn, Fe, NPK and Ca were not supplied in the experiment. The highest fat content was obtained in the absence of P and was significantly higher ($P \leq 0.05$) than other treatments except when N and P (combined) were absent. Complete nutrient also resulted in significantly ($P \leq 0.05$) lower fat content compared to the treatments without P and NP but was significantly higher in fat content compared to other treatments like deionised water, missing nutrients like N, K, Ca, PK, NPK, Fe, Mo, B and Mn. Plants grown under complete nutrient had a moisture content value that was not significantly different from the least moisture content. Other missing nutrients with values not significantly different from the least moisture content are B and NK. The moisture content was highest in the plants grown without Mn and was significantly higher than all other treatments. Plants grown without any nutrient, but only with the application of deionised water had similar moisture content compared to the plants grown with Cu as missing element. The ash contents ranged from 21.0 to 70.1%. The complete nutrient solution was in the middle level of the range while deionised water was in the lower range. The highest ash content was caused by nutrients without Cu (70.1%) and B (69.9%) while the lowest was observed without P (17.9%). Nutrient solution without Zn also resulted in high ash content (67.5%). The highest carbohydrate (CHO) content was observed when plants were grown without P and NP which were significantly ($P \leq 0.05$) higher than all other treatments except the plants grown without Mn. The least CHO content was observed in plants grown without Zn. Plants grown with complete nutrient had significantly lower CHO content compared with the one grown without application of any nutrient.The highest nutritive value was observed when NP was missing in the nutrients added. This was significantly ($P \leq 0.05$) higher than other treatments except when P was missing. The least nutritive value was also observed when Cu was missing in the nutrients. This was also significantly($P \leq 0.05$) lower than any other treatments except when B was missing. Complete nutrient and deionised water appeared to be on the upper middle range of the distribution of the nutritive values.

3.2.2 Nutrient uptake

Application of nutrient solution had significant ($P \leq 0.05$) effect on the uptake of N, P, K, Ca, Mg, K, Na, Mn, Fe, Cu and Zn by *Aloe vera* at 20 WAT (Table 3). *Aloe vera* plants in solution without K had the highest N uptake (50.1 mg g^{-1}dw) while those without Mn (8.3 mg g^{-1}dw), NP (9.5 mg g^{-1}dw) and NPK (7.6 mg g^{-1}dw) had the lowest. High N uptake was also obtained on *Aloe vera* plants in nutrients without Zn. (38.5 mg g^{-1}dw). Phosphorus and calcium uptakes were highest in nutrient without PK (41.1 mg g^{-1}dw) and K (314.4 mg g^{-1}dw) respectively while the corresponding lowest values occurred on plants without NK (4.3 mg g^{-1}dw) and Ca (44.7 mg g^{-1}dw). Those with complete nutrient and those without Zn also had high Ca and P uptake respectively.*Aloe vera* plants in nutrient solutions without N had the highest K uptake (89.5 mg g^{-1}dw) while those without NP (21.6 mg g^{-1}dw) had the lowest. Higher K uptakes were also observed in plants in nutrient solutions without Zn (72.5 mg g^{-1}dw), B (66.8 mg g^{-1}dw), K (78.2 mg g^{-1}dw) and S (68.7 mg g^{-1}dw) (Table 4.8). Conversely, Aloe *vera* plants in nutrient solutions without NPK had K uptake value (26.4 mg g^{-1}dw) comparable to the lowest. The highest Mg uptake (40.96 mg g^{-1}dw) was observed with plants in nutrient solution without Cu while those without Mn, (8.3 mg g^{-1}dw), NPK (9.2 mg g^{-1}dw), S (11.5 mg g^{-1}dw), P (13.5 mg g^{-1}dw) and deionised water (9.8 mg g^{-1}dw) had low values. Although lower than the highest, plants in nutrient solutions without Zn (23.8 mg g^{-1}dw), B (22.8 mg g^{-1}dw), PK (26.6 mg g^{-1}dw), K (33.5 mg g^{-1}dw) and N (25.3 mg g^{-1}dw) also had high Mg uptake. All plants in solution without K had Mg uptake value (33.5 mg g^{-1}dw) comparable to that without Cu (40.9 mg g^{-1}dw) and significantly higher than the lowest with deionised water and those with P, Ca, Mg, S, Mn and NPK (8.3 to 13.5 mg g^{-1}dw). *Aloe vera* plants in nutrient solution without K had high Na uptake value (0.06 mg g^{-1}dw) comparable to the highest (0.08 mg g^{-1}dw) of that without K and significantly ($P \leq 0.05$) higher than the lowest values of 0.005 to 0.04 mg g^{-1}dw. High Na uptakes were also observed in plants without N (0.05 mg g^{-1}dw), Zn (0.04 mg g^{-1}dw), S (0.04 mg g^{-1}dw) and those with deionised water (0.04 mg g^{-1}dw) also had significantly ($P \leq 0.05$) higher uptake than the lowest. Mn uptake (0.32 mg g^{-1}dw) of plants grown with nutrient solution without NP (0.28 mg g^{-1}dw) was comparable to the highest (0.32 mg g^{-1}dw) of plants in solutions without NK and significantly ($P \leq 0.05$) higher than the lowest of those with complete nutrient and others without Mn (0.01 mg g^{-1}dw), B (0.007 mg g^{-1}dw) and Mo (0.007 mg g^{-1}dw). Plants in nutrient solution without B had high Fe uptake value (0.25 mg g^{-1}dw) comparable to the highest of those without K (0.28 mg g^{-1}dw) and Zn (0.26 mg g^{-1}dw) while that without NPK had the lowest value of (0.01 mg g^{-1}dw). Furthermore, high Fe uptake values of 0.15 to 0.20 mg g^{-1}dw were also observed in plants without S, NK, PK, Mo and Cu. The uptakes of these treatments were also higher than the lowest. *Aloe vera* plants in nutrient solutions without B had the highest Zn uptake (0.14 mg g^{-1}dw) while those without N, K and Zn also had high Zn uptake values of 0.02, mg g^{-1}dw that were higher than the lowest which ranged between 0.00 and 0.007. Zinc was not detected in plants with deionised water and those without Fe, Mn and Cu.

IV. Discussion

The use of washed beach sand as the growth medium for the determination of limiting nutrient elements in the production of *Aloe vera* in the screenhouse, was to ensure that *Aloe vera* accessed only the elements in the nutrient solutions supplied. The pre-cropping analyses of the beach sand used in the study indicated slight alkalinity. The soils were therefore suitable for the propagation and growth of *Aloe vera* as earlier reported by ([26] and [27]). *Aloe vera* is a unique plant and response to nutrient differs from other plants. High protein content, was obtained when the plant was grown in soil without Ca and K, high fat content was obtained when grown without NP and P. High carbohydrate implies that even when grown under similar condition, the variation of what could be the major component would be unpredictable based on nutrient available for that plant during the growing period. This implies that if there is nutrient in the soil, carbohydrate content might be reduced. It is therefore, essential to know the end use of this plant for specific fertilizer recommendation to be made. This is in support of [28] that there is usually a significant improvement in both quantity and quality of plant growth when appropriate fertilizers are added. Furthermore, the least nutritive value and proximate composition of *Aloe vera* were obtained in plants without NPK thus confirming that a combination of N, P and K is the most limiting in *Aloe vera* production.This is in support of [28] that there is usually a significant improvement in both quantity and quality of plant growth when appropriate fertilizers are added. [12] have also recommended the application of 15 tons FYM and 50 kg each of nitrogen, phosphorus and potassium to *Aloe vera* for growth.The presence of these minerals N, P, K, Ca, Mg, Mn, Fe, Cu, and Zn in *Aloe vera* plant treated with different nutrient elements shows they are all important to the plant. Also, the significant difference in some of the mineral and proximate composition as affected by N, P and K fertilizer application reveal that leaf composition of nutrients is primarily controlled by nutrient supply ([29]; [30]).

V. Conclusion

To achieve maximum nutrient composition, uptake and nutritive value of *Aloe vera*, external source of nitrogen, phosphorus and potassium will be necessary. Further research efforts should be targeted at determination of optimum rates of nitrogen, phosphorus and potassium for enhanced yield and nutrient composition.

Table 1 Physical and chemical properties of the experimental soils

Properties	Beach sand	
pH (H_2O) (1:1)	7.4	
Organic carbon (g kg^{-1})	1.4	
Total N (g kg^{-1})	0.009	
Available P (mg kg^{-1})	1.02	
Exchangeable cations (cmol kg^{-1})		
K	0.17	
Mg	0.33	
Ca	0.89	
Na	0.09	
Exchangeable Acidity (cmol kg^{-1})	0.20	
ECEC (cmol kg^{-1})	1.68	
Base saturation (g kg^{-1})	880.09	
Extractable micro nutrient (mg kg^{-1})		
Mn	87.44	

Fe	66.00	
Cu	1.18	
Zn	5.36	
Particle size distribution (g kg^{-1})		
Sand	930	
Silt	20	
Clay	50	
Textural class	Sand	

Table 2 Effects of missing nutrients on proximate composition (%) and nutritive value (Cal / 100g) of *Aloe vera* at 6 months after transplanting

Treatment	Protein	Fat	Moisture content	Ash	Carbohydrate	Nutritive value (Calorie / 100g)
			(%)			
[1]De -H_2O	1.8def	0.9cd	5.4c	31.0gh	60.4bc	257. 6cd
[2]- N	3.5b	0.4efg	4.0d	29.8h	62.1bc	268.4bc
- P	2.8c	2.2a	6.4b	17.9l	70.8a	310.7a
- K	4.6a	0.6de	3.4f	39.1e	52.8d	233.2e
- Ca	4.5a	0.1fg	3.8de	30.3gh	61.4bc	264.9bc
- Mg	3.3b	1.2bc	4.1d	28.7i	62.6bc	274.8b
- S	2.8c	1.1bc	3.7ef	30.2gh	62.0bc	269.6bc
- PK	2.0de	0.6de	3.9de	31.3fg	62.1bc	262.4bcd
- NK	2.0de	1.2bc	2.3h	41.0d	53.4d	232.5e
- NP	1.9def	2.1a	2.9g	21.0k	72.1a	314.5a
- NPK	1.4fg	0.1fg	3.4f	51.3c	45.5e	181.4f
- Fe	3.3b	0.1fg	3.1g	32.4f	59.1cd	250.0d
- Mo	2.2d	0.4efg	2.8g	52.3c	42.1ef	132.0g
- B	1.3g	0.2efg	2.1h	69.9a	26.4g	113.1h
- Zn	2.7c	1.4b	1.3i	67.5b	27.1g	275.1b
- Mn	2.1de	0.1fg	6.7a	24.7j	66.3ab	180.9f
- Cu	1.7efg	1.1bc	5.6c	70.1a	21.2g	102.8h
Complete Nutrient	3.7b	1.4b	2.4h	41.3d	36.95f	231.9e

Means with the same letter(s) in each column are not significantly different using Duncan's Multiple Range Test at 5% probability level.

[1]De-H_2O - Deionised water [2] – – Indicates the missing nutrient in the medium

Table 3 Effects of missing nutrients on nutrient uptake of *Aloe vera* at 6 months after transplanting

Treatment	N	P	Ca	K	Mg	Na	Mn	Fe	Zn
					(mgg^{-1} dw)				
[1]De-H_20	13.6h	5.0j	68.3j	33.1h	9.8c	0.04bcd	0.03bc	0.04hi	0.00c
[2]- N	27.8c	13.3d	179.5e	89.5a	25.3abc	0.05bc	0.18abc	0.11efg	0.02b
- P	14.1gh	4.7jk	99.8hi	50.7f	13.5c	0.02de	0.07abc	0.05ghi	0.007bc
-K	50.1a	19.2c	314.4a	78.2b	33.5ab	0.08a	0.07abc	0.28a	0.02b
- Ca	19.3ef	5.6i	44.7k	45.8fg	11.5c	0.02de	0.18abc	0.09fgh	0.007bc
- Mg	13.4h	8.3g	97.6hi	33.3h	8.3c	0.02de	0.06bc	0.08gh	0.005c
- S	20.6e	11.4f	231.6c	68.7c	11.4c	0.04bcd	0.14abc	0.20bc	0.005c
- NK	14.3gh	4.3k	137.2h	44.2fg	13.8bc	0.06ab	0.32a	0.19cd	0.005c
- PK	27.5c	41.1a	184.7e	44.2fg	26.6abc	0.03cde	0.06bc	0.14def	0.005c
- NP	9.5i	5.9i	57.8jk	21.6j	14.1bc	0.01e	0.28ab	0.05ghi	0.005c
- NPK	7.6i	2.3l	55.5jk	26.4ij	9.2c	0.02de	0.05bc	0.005i	0.007bc
- Fe	16.3gh	7.3h	107.2h	51.3def	14.3bc	0.03cde	0.06bc	0.05hi	0.000c
- Mn	8.3i	4.8j	87.3i	32.1hi	8.3c	0.005e	0.01c	0.06ghi	0.000c
- B	16.9fg	12.7e	212.4d	66.8c	22.8abc	0.05bc	0.007c	0.25ab	0.14a
- Mo	23.7d	11.5f	166.5ef	56.2de	21.1bc	0.0cde	0.007c	0.15cde	0.007bc
- Zn	38.5b	27.5b	213.9d	72.5bc	23.8abc	0.04bcd	0.17abc	0.26a	0.02b
- Cu	14.3gh	12.7e	154.3fg	37.7h	40.96a	0.03cde	0.11abc	0.16cde	0.000c
Complete nutrient	27.8c	11.1f	253.3b	57.5d	16.8bc	0.03cde	0.01c	0.08gh	0.007bc

Means with the same letter(s) in each column are not significantly different using Duncan's Multiple Range Test at 5% probability level. [1]De-H_2O - Deionised water [2] □–□ – Indicates the missing nutrient in the media

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