LAUCER 1(2):12-22 LAUTECH Crop and Environmental Reviews
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Determination of Critical Nutrients for Growth, Yield and Deficiency Symptoms of Aloe Vera

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Abstract
Aloe vera cultivation has acquired great commercial importance for medicinal and cosmetics processing. However, there is paucity of research-based fertilizer recommendations for enhanced growth and adequate nutrient composition of this crop. Experiment was conducted to assess the growth response of the plant to nutrient elements and the deficiency symptoms. Using 2 kg of washed beach sand per pot, a missing nutrient experiment of 18 treatments comprising macronutrient, micronutrient and their combinations was laid out in completely randomised design and replicated four times, and monitored for seven months. 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) were measured and analysed using descriptive statistics and ANOVA at p = 0.05. Results showed that LL, LW, LT, NS were lowest for treatments without N, P and K indicating that these were the most limiting macronutrients. Complete nutrient had better growth while plants grown in deionized water, -N, -K, -NP, -PK and -NPK had stunted growth and yellowing of leaves. Aloe vera requires the three primary nutrients (N, P and K) for optimal growth, nutrient composition and quality.

Keywords: Aloe Vera; Deficiency Symptoms; Nutrient Solution; River Sand; Suckers

Introduction
Aloe vera, a semi-tropical plant and an all-purpose herbal plant has been at the center of renewed interest in the global market because of its therapeutic and nutritive substances extracted from leaves, used in commercial preparations for pharmaceutical, cosmetic and as a fresh food (International Aloe Science Council, 2002; Cristiano *et al*, 2016; Gutterman and Chauser-Volfson, 2007).

Aloe vera leaf is widely known to contain unique organic phytochemicals in its leaves that favour human health (Ahlawat and Khatkar 2011, Chun-hui *et al.,* 2007, Lucini *et al.*, 2015). Most recent studies were carried out in order to evaluate its role in the control or cure of many human diseases, e.g. for controlling gastric injuries (Yusuf *et al.,* 2004), for anti-microbial activity (Moody *et al.,* 2004), for defending against hippocampus and cerebral cortex oxidative damage (Parihar *et al*, 2004) for curing acne (Orafidiya *et al,* 2004), for anti- inflammatory activity (Vazquez *et al*, 2004) and other medical conditions.

Like any other plant, *Aloe vera* plants require the right kind of nutrients to sustain their growth and development. Adequate and proper balance of the plant nutrients is essential for rapid growth and maximum yield of crops (PCARRD, 1983). In crop production, the plant nutrients supplied by the soil are often inadequate and in many cases are in forms not readily available for immediate use by the growing crop. These call for augmentation of soil nutrients with fertilizers to improve their performances. Beach sand was collected from Lagos Lagoon, sieved through 2 mm mesh and washed with water to leach out the nutrients. It was sun-dried and subjected to laboratory analysis before use. The beach sand used as a growth medium in this experiment ensures that it is only the nutrient fed to the plant that it feeds on. This will authenticates any observations made because it eliminates the bio factor which are the reservoir of nutrient elements in arable soil and also allow easy identification of the effects of the missing nutrient solution applied. Likewise, the symptoms of deficient or missing nutrient will be easily detected.

Furthermore, fertilizers are needed to ensure optimum supply of needed nutrients to cultivated plants. The effects of proper use of fertilizers can be seen in the early establishment of the plant, good stand, increase vigour and greater

resistance to pests and diseases. At harvest time, these effects are summed in terms of high yield, improved crop quality and more profit to the farmer (Owoade *et al.,* 2017, Iren *et al.*, 2014).

With the recent drive towards the multipurpose use of *Aloe vera* in Nigeria, the judicious use of production inputs like fertilizers among others for optimum yield need to be examined. Fertility in agronomic management is one strategy to boost the Aloe yield, however to reduce production costs Aloe fields are often not fertilized. *Aloe vera* has been used worldwide both in pharmaceutical, food and cosmetic industries (Campestrini *et al.,* 2006). In spite of proven medicinal properties and the increase in industrial and domestic uses of *Aloe vera*, there are little information on the effect of fertilizer use or its application. It is essential to have an appropriate fertilizer recommendation for enhanced yield and nutrient composition. This informed this study in which critical nutrients needed for growth, yield and response to macro and micronutrient application to *Aloe vera* were investigated.

Materials and Methods

A screen house experiment was conducted in the Derived savannah agro-ecological zone of Southwestern Nigeria at Ladoke Akintola University of Technology Ogbomoso.

Soil sampling and preparation

Beach sand was collected from Lagos Lagoon, sieved through 2 mm mesh and washed with water to leach out the nutrients. It was sun-dried and subjected to laboratory analysis before use. A transparent plastic pot containing 2 kg sand was placed on another white plastic pot that has the nutrient solution (Fig.1). A wick was used to convey water containing nutrient from below to the sand because sand is not able to retain water.

Soil Analysis

Representative soil 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 0.5 mm mesh was used for both the determination of total nitrogen (N) and organic carbon. Particle size analysis was carried out according to Bouyoucous (1951) hydrometer method using sodium hexametaphosphate as the dispersant. Soil pH was determined in 1:1 soil water ratio (IITA, 1982; Black *et al.,* 1965). Total N was extracted by the macro–Kjeldahl digestion method (Bremner, 1982) followed by colorimetric determination using Technicon Autoanalyser. 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) (Melich, 1984). 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 Spectrophotometer (AAS) (Model Buck 200A). Sodium (Na) and K were determined using Flame emission photometer. Exchangeable acidity was determined by KCl extraction method (Mclean, 1965). 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 (Heanes, 1984).

Nutrient Application

Macronutrient (N, P,K, Ca, Mg and S) and micronutrient (Cu, Mn, Mo, B, Zn and Fe) 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 soil was watered to field moisture capacity and left for 48 hours to equilibrate.

There were 18 treatments consisted of the following:

i. One complete nutrient (N, P, K, Ca, Mg, S, Cu, Zn, Fe, Mn, Bo and Mo) application,
ii. Twelve treatments with one of the nutrients element in (i) above missing,
iii. Four treatments having a combination of two or three macronutrients missing (i.e. N and P, N and K, P and N, P and K) and
iv. control (Deionised water).

Modified Jensen's solution method (Roughly, 1984) 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

$Na_2MoO_4.2H_20$. Ten millilitres 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.

Planting of *Aloe vera, sampling and analysis*

The18 treatments each were replicated four times to give a total of 72 experimental units and arranged in a completely randomized design. Two months old suckers collected from the Department of Agronomy, University of Ibadan, Ibadan were weighed before transplanting in each of the transparent plastic containing 2 kg sand.

After harvesting, all shoots and roots were freeze-dried at a temperature of -50 °C to a constant weight for five days for dry weight determination.

Data Collection

Data were collected on growth: leaf length, leaf width and leaf thickness. Data were also collected on indices of yield in *Aloe vera*, and these are number of leaves and suckers, leaf volume and weight gained.

Data collection, which commenced two weeks after transplanting till 7 months after transplanting was at four weeks interval. Leaf length was determined as the distance from the base to the tip of the longest leaf. Leaf thickness was determined using Vernier callipers. Leaf width was determined at the centre of the longest leaf while count of leaves considered all fully opened leaves per plant. Leaf volume was calculated based on the shape of the plant using the formular V = (Length / 12) x 3.142 x Weight x Thickness (Alagunkannan *et al,* 2006, Hemandez–Cruz *et al,* 2002). Initial and final weights of the plants were determined. Deficiency symptoms noticed were recorded.

At 20 weeks, three (3) plants per treatment were uprooted, washed several times with deionised water to remove contaminants, weighed and stored at 4 °C for two weeks before freeze-drying at -50 °C.

Data Analysis

Data collected were subjected to analysis of variance and treatments means were compared using Duncan's Multiple Range Test. Correlation analyses was conducted between every pair of measured parameters using PROC CORR and regression analysis was also carried out with SAS software using PROC REG (SAS, 2009)

Results and Discussion

Physical and chemical characteristics of the experimental soil

The physical and chemical properties of the soil used for the experiment are presented in Table 1. The pH for the beach sand was slightly acidic and contains 930, 20 and 50 g kg^{-1} sand, silt and clay respectively, and belongs to the textural class sand. The organic carbon, N and P, Exchangeable bases and micronutrients of the beach sand were very low. The pre-cropping analyses of the beach sand used in the study that indicated slight alkalinity shows that the soil was therefore suitable for the propagation and growth of *Aloe vera* as earlier reported by (Anon, 2000 and 2007), The levels of nitrogen and phosphorus in the sand were below the critical levels (Uponi and Adeoye, 2000) while the levels of K content did not facilitate good response to other externally applied nutrients as earlier reported by Owoade *et al* (2008) that potassium is essential and required in large quantity by *Aloe vera* but the optimum rates had not been determined. The beach sands were also suitable for propagation of the plant since it has been reported to grow successfully in such type of soils (Anon, 2000).

Effects of Missing Nutrients on the Vegetative Growth of *Aloe Vera*

Number of leaves of *Aloe vera* was significantly affected by nutrient application at 4 to 20 WAT (Table 2). The plants provided with complete nutrients produced the highest number of leaves at 8, 12 and 16 WAT but were not significantly different from plants with only deionised water, those with Ca, NP, Fe and Cu as missing elements. Some other missing elements such as P, K, Mg, B and Zn were not consistent in the trend of their growth as some were not significantly different from the highest at some growth intervals but were significantly lower at some other growth intervals. Notably, Mn as missing element was not significantly different from the highest number of leaves at 4 WAT, but subsequently, it was consistently significantly lower compared to the highest value till 20 WAT.

The leaf length of *Aloe vera* generally increased with age in all the treatments from 4 WAT to 20 WAT (Table 3). Application of nutrients had significant effect on leaf length of *Aloe vera* at 20

WAT with plants of the treatment that excluded B producing the highest length of 16.45 cm while those without NP (11.60 cm) and those with deionised water (10.93 cm) had significantly lower leaves.

Table 1: Physical and chemical properties of the experimental soils

Parameters	Value	Units	Level
pH (H_2O) (1:1)		7.4	Slightly acidic
Organic carbon	(g kg^{-1})	1.4	Low
Total N (g kg^{-1})	(g kg^{-1})	0.009	Low
Available P	(mg kg^{-1})	1.02	Low
Exchangeable cations			
K	(cmol kg^{-1})	0.17	Medium
Mg	(cmol kg^{-1})	0.33	Medium
Ca	(cmol kg^{-1})	0.89	Low
Na	(cmol kg^{-1})	0.09	Low
Particle size distribution			
Sand	(g kg^{-1})	930	
Silt	(g kg^{-1})	20	
Clay	(g kg^{-1})	50	
Textural class			Sand

Source: Chude *et al.*, 2011, ESU, 1991

Table 2: Effects of missing nutrients on number of leaves of *aloe vera* at different weeks after transplanting

	Weeks after Transplanting				
Treatment	4	8	12	16	20
[1]De-H_20	6.25abc	7.50abc	7.50ab	7.75abc	7.50abc
[2]- N	5.50bcd	5.75c	6.25b	7.25abc	7.25abc
- P	4.50d	6.00c	6.25b	7.00abc	7.75ab
- K	6.25abc	6.25bc	6.75ab	8.50ab	8.75ab
- Ca	7.75a	6.75abc	7.75ab	8.25abc	7.25abc
- Mg	5.50bcd	6.00c	6.00c	6.50bc	7.00abc
- S	6.25abc	6.25bc	7.00ab	7.50abc	8.25ab
- NK	5.75bcd	6.00c	6.00	7.50abc	7.75ab
- PK	5.75bcd	6.25bc	6.50b	6.00c	6.50bc
- NP	6.25abc	7.00abc	6.00c	8.25abc	7.75ab
- NPK	6.25abc	6.00c	6.00c	7.00abc	7.50abc
- Fe	6.25abc	6.50abc	7.25a	7.00abc	8.00ab
- Mn	6.25abc	5.75c	7.00abc	6.00c	5.50c
- B	5.25cd	6.50abc	7.00ab	7.50abc	8.25ab
- Mo	6.00bcd	6.25bc	7.25ab	7.25abc	7.75ab
- Zn	6.50abc	6.50abc	6.50b	7.50abc	9.25a
- Cu	6.75abc	6.75abc	7.00ab	7.50abc	8.75ab
Complete nutrient	7.00ab	8.25a	8.50a	9.25a	8.75ab

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_20 - deionised water

[2] '–' – Indicates the missing nutrient in the media

Table 3: Effects of missing nutrients on leaf length (cm) of *aloe vera* at different weeks after transplanting

	Weeks after Transplanting				
Treatment	4	8	12	16	20
[1]De-H_20	10.70	10.60	11.60	11.68	10.93b
[2]- N	10.75	11.55	11.70	12.33	12.40ab
- P	11.75	12.18	12.50	12.83	13.00ab
- K	10.50	10.88	11.28	11.98	13.50ab
- Ca	9.98	10.30	12.05	12.80	13.18ab
- Mg	10.93	11.68	12.05	12.05	12.13b
- S	12.43	12.88	13.28	13.65	13.73ab
- NK	12.10	12.15	12.20	12.40	12.53ab
- PK	12.10	12.63	12.93	13.60	13.83ab
- NP	10.20	10.83	11.15	11.48	11.60b
- NPK	11.23	11.88	12.00	12.15	12.30ab
- Fe	12.03	12.25	12.38	13.38	13.50ab
- Mn	13.40	13.65	13.80	13.95	14.13ab
- B	13.03	13.40	13.55	13.88	16.45a
- Mo	10.25	10.45	10.70	10.93	12.10b
- Zn	11.60	12.00	12.38	13.38	13.85ab
- Cu	11.88	12.48	13.85	14.23	14.53ab
Complete nutrient	11.48	11.53	11.78	12.78	14.90ab

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_20 – deionised water

[2] '–' – Indicates the missing nutrient in the media

Table 4: Effects of missing nutrients on leaf width (cm) of *aloe vera* at different weeks after transplanting

	Weeks after transplanting				
Treatment	4	8	12	16	20
- [1]De-H_2O	1.08abcde	1.08ab	1.13cdef	1.23cd	1.63bcde
[2]- N	1.08abcde	1.13ab	1.18abcdef	1.28bcdef	1.70bcde
- P	1.25a	1.28a	1.28abcd	1.35bcd	1.55cde
- K	1.05bcde	1.13ab	1.20abcdef	1.30bcd	1.83abcd
- Ca	0.98de	1.05ab	1.10cdef	1.25bcd	1.55cde
-Mg	1.05bcde	1.18ab	1.33abc	1.40bcd	1.53cde
- S	1.18abc	1.28a	1.38ab	1.38bcd	1.55cde
- NK	1.11abcd	1.15ab	1.25abcde	1.25bcd	1.40de
- PK	1.10abcde	1.20ab	1.23abcdef	1.30bcd	1.38de
- NP	0.93e	1.00b	1.13cdef	1.23cd	1.43de
- NPK	1.08abcde	1.10ab	1.15bcdef	1.15cd	1.28e
- Fe	1.00cde	1.03b	1.15bcdef	1.48bc	1.75bcde
-Mn	1.03bcde	1.03b	1.03ef	1.28bcd	1.73bcde
- B	1.08abcde	1.13ab	1.23abcdef	1.60ab	2.23a
- Mo	0.98de	1.00b	1.00f	1.25bcd	1.85abcd
- Zn	1.00cde	1.03b	1.05def	1.08d	2.05ab
- Cu	1.08abcde	1.18ab	1.23abcdef	1.40bcd	1.95abc
Complete nutrient	1.20ab	1.20ab	1.40a	1.85a	2.05ab

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

Table 5: Effects of missing nutrients on leaf thickness (cm) of *Aloevera* at different weeks after transplanting

	Weeks after transplanting				
Treatment	4	8	12	16	20
[1]De-H_2O	0.26ab	0.28b	0.30	2.18ab	2.18cd
[2]- N	0.30ab	0.35ab	0.39	2.20a	2.28abc
- P	0.34a	0.36ab	0.38	2.05bcd	2.10de
- K	0.28ab	0.33ab	0.34	2.13abcd	2.33ab
- Ca	0.28ab	0.35ab	0.33	2.10abcd	2.15cde
- Mg	0.26ab	0.36ab	0.44	2.13abcd	2.15cde
- S	0.29ab	0.35ab	0.40	2.13abcd	2.18cd
- NK	0.26ab	0.30ab	0.46	2.10abcd	2.15cde
- PK	0.33a	0.31ab	0.38	2.13abcd	2.10de
- NP	0.29ab	0.33ab	0.35	2.10abcd	2.18cd
- NPK	0.26ab	0.30ab	0.40	2.00d	2.03e
- Fe	0.28ab	0.35ab	0.31	2.03cd	2.10de
- Mn	0.30ab	0.39ab	0.38	2.10abcd	2.33ab
- B	0.30ab	0.35ab	0.38	2.05bcd	2.38a
- Mo	0.29ab	0.33ab	0.51	2.03cd	2.28abc
- Zn	0.31a	0.38ab	0.55	2.08abcd	2.33ab
- Cu	0.29ab	0.40a	0.46	2.03cd	2.23bcd
Complete nutrient	0.21b	0.28b	0.50	2.15abc	2.23bcd

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

Table 6: Effects of missing nutrients on number of suckers of *Aloe vera* at different weeks after transplanting

	Weeks after transplanting			
Treatment	8	12	16	20
[1]De-H_2O	0.25ab	0.50ab	0.75	0.75ab
[2]- N	0.25ab	0.25b	0.50	0.75ab
- P	1.25ab	1.25ab	1.25	1.25ab
- K	1.75a	1.75ab	2.00	2.25ab
- Ca	1.50ab	2.00a	2.00	2.75a
- Mg	0.25ab	0.25b	0.75	1.00ab
- S	0.75ab	0.75ab	0.75	1.00ab
- NK	1.00ab	1.25ab	1.50	1.50ab
- PK	0.25ab	0.25b	0.25	0.25b
- NP	0.50ab	0.50ab	0.50	1.00ab
- NPK	0.00b	0.50ab	0.50	0.50b
- Fe	0.00b	0.25b	0.75	1.00ab
- Mn	0.75ab	0.75ab	1.00	1.00ab
- B	0.25ab	0.25b	1.75	2.25ab
- Mo	0.75ab	1.00ab	1.75	2.00ab
- Zn	0.75ab	0.75ab	0.75	0.75ab
- Cu	1.00ab	1.00ab	1.00	1.25ab
Complete nutrient	0.25ab	0.75ab	1.25	1.50ab

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

Table 7: Correlation coefficients (r) among yield components of *Aloe vera* as influenced by missing nutrients (n = 72)

	Number of leaves	Leaf Length	Leaf Width	Leaf thickness
Leaf length	0.25*			
Leaf width	0.55*	0.55*		
Leaf thickness	0.29**	0.45*	0.66*	
Number of suckers	0.25*	0.25*	0.28*	0.14*

**, ** significant at P < 0.05 and P < 0.01, respectively*

Effects of nutrient application on the leaf width of *Aloe vera* were significant at different periods of growth (Table 4). Consequently, complete nutrient maintained a significant high leaf width which was either the highest, or was not significantly different from the highest value from 4 to 20 WAT. Elements like P, Ca, S, Mg and combinations of NK, PK, NP and NPK initially were not critical from 4 to 12 WAT, but became significantly reduced in leaf width from 16 to 20 WAT compared to the highest value. Absence of B was not critical to the development of leaf width from 4 to 20 WAT as the values obtained were either the highest or not significantly different from the highest. Absence of Mo and Zn at 4 to 16 WAT resulted in significantly lower leaf width compared to that of complete nutrient, but at 20 WAT, were not significantly different from the highest leaf width or leaf width obtained under complete nutrient.

Absence of N, K, Mn and Zn did not significantly influence the leaf thickness *of Aloe vera* from 4 to 20 WAT (Table 5). All treatments have no significant effect on the leaf thickness at 12 WAT. Highest leaf thickness of *Aloe vera* was not with a consistent trend at different period of evaluation. At 4 WAT, absence of P resulted in highest leaf thickness, while absence of Cu was the treatment with highest leaf thickness at 8 WAT. At 20 WAT, the highest leaf thickness was obtained when B was absent. Absence of Ca, Mg, S, combination of NK, PK, NP as well as deionised water resulted in leaf thickness that were not significantly different from the highest values at 4 to 16 WAT, but resulted in significantly lower values compared to that of the highest leaf thickness at 20 WAT. Similarly, absence of NPK, Fe and Cu were significantly lower compared to the highest value of leaf thickness at 16 and 20 WAT.

The least number of suckers was observed under the treatment without PK at 12 to 20 WAT (Table 6) but was only significantly lower than the highest at 12 and 20 WAT which was obtained when Ca was not applied. Although absence of B at 8 and 12 WAT showed low number of suckers and was even significantly lower compared to the number of suckers in the absence of Ca at 20 WAT, yet at 20 WAT, absence of B resulted in number of suckers that was not significantly different from the highest value obtained under the treatment without Ca. Complete nutrient and control maintained a relatively stable number of suckers that was not significantly different from the number of suckers obtained at different periods of evaluation.

The results obtained on the vegetative growth might be because plants require adequate supply of essential elements to complete their life cycle (Annaduri *et al,* 1994). Deficiency of any essential element adversely affects plant growth, resulting in failure to complete the vegetative or / and reproductive stage, premature senescence and even death. On the other hand, the deficiency symptoms can be prevented or rectified by supplying the relevant elements as nutrients. Both major and minor nutrient elements are essential for crop production. Adequate N, P and K, each at 50 kg/ha of the elements was however reported to increase growth and leaf yield of *Aloe indica* in India (Hossain *et al,* 2007). Reports showed that in Bangladesh and Mexico, there was an increase in number, size and yield of *Aloe vera* when N fertilizer were applied (Hasanuzzaman *et al* 2008, Murillo-Amador *et al* 2007),. Wabuyele *et al.* (2006) suggested that excess N could reduce gel quality of *Aloe vera* while inadequate level of N shortens the plant life cycle, resulting in early maturity and poor economic yield (Mengel and Kirkby, 1987). In this study, plants given complete nutrient had normal growth with healthy green foliage. In contrast, *Aloe ver*a plants grown in beach sand with nutrients without K, N, P, NP, PK and NPK had reduced leaf length, width and thickness compared to those in complete nutrient. These revealed the severity of their deficiency and or inadequacy on *Aloe vera* growth especially when the values obtained from plants treated without each one of NPK solutions was compared with that from complete nutrient solution. Significantly longer, wider and thicker leaves of

Aloe vera were observed in treatment without B compared to those with deionised water and complete nutrient. This indicates that B may not be an essential element for the good growth of *Aloe vera* and its presence can result in retarded growth and development. Treatments without Zn, NP, Ca and P produced the highest number of suckers, leaves and more nutritive values than others. Treatments without NPK combined and Fe did not produce suckers until 12 WAT while that without PK resulted in the lowest sucker production from 8 to 20 WAT. This shows the importance of P and K especially when combined as well as Fe in *Aloe vera* production. Similar trend as in leaf length, width and thickness of leaf was observed in respect of number of leaves per plant, with the exception of number of leaves obtained from those treated with nutrient without N, P, K, Ca, Mg, S, NK, NP and NPK. Comparatively lower numbers of leaves were produced than that of complete nutrient solution. This therefore, indicates that complete essential nutrients are required by plants for proper physiological development. This is in agreement with the work of Hossain *et al* (2007). The most limiting element for number of leaves is Mn and least is Zn. For leaf width, most limiting is NPK and least is Zn and Boron. The most limiting for leaf length are N and P while the least limiting is Boron. For leaf thickness, the most limiting is NPK and least is Boron. Most limiting elements for number of suckers are PK and NPK respectively.



Plate 1: Effect of missing macronutrient elements on *Aloe vera* plant. (Arrows indicates stunted growth, purple coloration on the leaves of –NPK treatment)

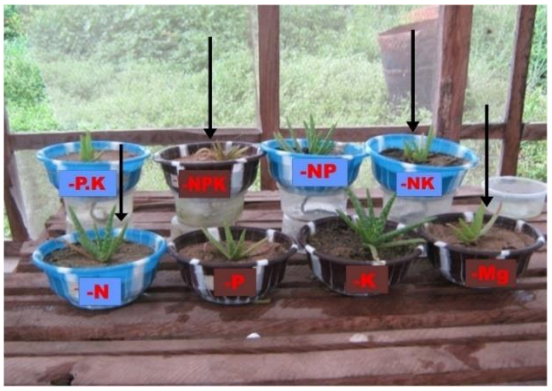


Plate 2: Effect of missing nutrient and elimination of two nutrients in *Aloe vera* plant (arrows indicates chlorosis, stunted growth on –NPK, -NK, -N, –Mg treatments)



Plate 3: Response of *Aloe vera* to different nutrients (arrows indicates purple colorations, stunted growth in –NP, -P, -S, -PK treatment).

Deficiency Symptoms of the Missing Nutrient on the Macronutrient

Deficiency symptoms of the missing nutrient on the macronutrient and elimination of the element are shown in plates1 to 3. Deficiency symptoms like chlorosis, for treatment without N, purple colourations for treatment without P, undersized leaves for treatment without K, stunted growth, were observed on treatment without N, P and K. *Aloe vera* plants in pots that had nutrient solutions without nitrogen, phosphorus and potassium combined exhibited purple colorations (-P) chlorosis (-N), stunted growth (-N and -K), burning of leaves at tips and undersized leaves (-K). These observations are consistent with those reported earlier for crops like okro, wheat and pasture (Akanbi, 2002), Stout *et al* (2000), Tejada *et al* (2005) and Enwezor *et al* (1989). Agbede (2009) and FFD (2012) attributed the purple colouration in P deficient plant to high anthocyanin content in the plant, the chlorosis in N deficient one to xanthophyll and chlorophyll precursors, stunted growth, due to N and K deficiency. The chlorosis of the leaves of N deficient plant may be due to less chlorophyll in the chloroplast, a situation which will

lead to reduction in the net assimilation rate. Consequently, these results induced disruption of Mg absorption and utilization, hence yellowing appearance of the plant. The burning of the leaves and undersized leaves due to K absence in nutrient solution was due to acid–base (ionic) imbalance of plant body system. The purple colouration in the absence of P may be due to reduction in phosphorylation, carboxylation and oxidation of food reserve to give energy (Agbede, 2009 and FFD, 2012).

Correlation Coefficients (R) Among Yield Components as Influenced by Missing Nutrients in *Aloe Vera* Plant

With the exception of number of suckers and leaf thickness, all the yield and yield component of *Aloe vera* treated with different nutrients had positive relationship among themselves (Table 7). Leaf thickness and number of leaves were highly significantly correlated ($P < 0.01$) though the highest correlation value was observed between leaf width and leaf thickness.

Conclusion

In the screenhouse, growth parameters of *Aloe vera* were differentially affected by absence of various elements in the nutrient solutions. The most limiting elements whose absence affected various growth of *Aloe vera* were; Mn for number of leaves, N, P and K for leaf width and thickness, N and P for leaf length as well as combination of P and K as well as N, P and K for number of suckers. Conversely, the least limiting elements whose absence in the growth medium did not affect growth parameters were; Zn for number of leaves, Zn and B for width of leaves, B for length and thickness of leaves and K for number of suckers of *Aloe vera*. The deficiency symptoms observed with each of the nutrient were leaf chlorosis and stunted growth for N, chlorosis, purple colouration, necrosis of tip, small size of leaves for combination of N, P and K. Conclusively, N, P, K and Mn could be considered critical nutrient for the growth and yield of *Aloe vera*. Further research efforts should be targeted at determination of optimum levels of the critical elements in sand medium.

References

Agbede, O. O. (2009). Understanding Soil and Plant Nutrition. Salman press and co. Keffi Nasarawa. 259pp

Ahlawat, K. S. and Khatkar, B. S. (2011). Processing, food applications and safety of *Aloe vera* products: a review. *Journal of Food Science and Technology*. 48: 525-533.

Akanbi, W. B. (2002). Growth, nutrient uptake and yield of maize and okra as influenced by compost and nitrogen fertilizer under different cropping systems. (Thesis). Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria.

Alagukannan, G, Ganesh S. and Gopal, S. K. (2006). Characterization and screening of different ecotypes of *Aloe vera* Linn. for growth, yield and quality. Research paper submitted for Yun-Ho Lee Award. *International Aloe Science Council.* Texas. 48p.

Anon. (2000). *Aloe vera.* http://www.ikisan.com/banhtm/aloe-vera-shtml (Accessed on 2 June, 2000)

Anon. (2007). Aloe India. (http://aloeindia.com/FAQS.HTM) (Accessed on 26 October, 2007).

Annaduri, K., Seshadri P. and Palaniappan, S. (1994). Influence of potassium levels on yield and oil content in sunflower soybean sequence. *Journal of Potassium Research* 10:124–129.

Anselm, A. (2004). Nature Power. 3rd edition, Fr. Anselm Adodo, OSB Ewu-Esan, Nigeria 288p.

Black, C. A, Evans, D. D. White, J. L., Enaminger, E. E. and Clark F. E (1965). Methods of Soil Analysis: In CA Black (Eds). American society of Agronomy Monograph No 9, Part 2. Madison, Wisconsin 986-994

Bouyoucous, G. H. (1951). A recalibration of hydrometer method for making of soil. *Agronomy Journal* 43:434-438.

Bremner, J. M and Mulvaney, C. S. (1982). Nitrogen-Total. In: Page, A. L, R. H Miller and D.R Keeney. (Eds.). Methods of soil analysis. Part 2, Chemical and microbiological properties, 2nd (Agronomy series no 9) ASA, SSSA, Madison Wisconsin 595-624pp.

Campestrini, L. H. (2006). Cloning protocol of *Aloe vera* as a study case for "Tailor-made" Biotechnology to small farmers. *Journal of Technology Management and Innovation* 1.5:76–79.

Chude, V. O, Gladiola S. O, Osoh A. O. and Daudu C. K. (2011). Fertilizer use and management practices for crops in Nigeria. Fourth edition. Federal fertilizer department, Federal ministry of agriculture and rural development, Abuja, Nigeria. 59p

Chun-hui, L., Chang-hai, W. Zhi-liang, X and Yi, W. (2007). Isolation, characterisation and antioxidant activities of two polysaccharides from the gel and the skin of Aloe barbadensis Miller irrigated with sea water. *Process Biochemistry*. 42:961-970. 10.1016/j.procbio.2007.03.004

Cristiano, G., Murillo-Amador, B. and De Lucia, B. (2016). Propagation techniques and agronomic

requirements for the cultivation of Barbados Aloe (*Aloe vera* (L) Burm. F.). *Front. Plant science*. https://doi.org/10.3389/fpls.2016.01410

Enwezor, W. O, Udo, E. J., Usoroh, N. J. , Ayotade, K. A., Adepetu, J. A. Chude, V. O. and Udegbe, C. I. (1989). Fertilizer Use and Management Practices for Crops in Nigeria. Series No. 2. Bobma Publishers, U.I. Ibadan, Nigeria. 15p.

Esu, I. E. (1991). Detailed soil survey of Nihort farm at Denkure Kano state Nigeria. Institute for agricultural research, Ahmadu Bello University, Zaria, Nigeria. 72pp

Fageria, N. K. (1989). Response of Cowpea to Phosphorus on an Oxisol with Special Reference to Dry Matter Production and Mineral Ion Content. *Tropical Agriculture* (Trinidad) 68:384–387.

Fageria, N. K. and Baliger, V. C. (1997). Phosphorus-use efficiency by corn genotypes. *Journal of Plant Nutrition* 20.10:1267-1277.

F.F.D. (Federal Fertilizer Department). (2012). Fertilizer use and management practices for crops in Nigeria. 4th Edition. Edited by VO Chude, SO Olayiwola, C Daudu and A Ekeoma Federal Ministry of Agriculture and Rural Development, Abuja. 224pp.

Gutterman, Y. and Chauser-Volfson, E. (2007). Secondary phenol metabolites (SPhMs), distribution and content of some Aloe species, originated from arid zones of South Africa: a review. *American Journal of Food Technology* 2: 255-569. 10.3923/ajft.2007.555.569

Hasanuzzaman, M, Ahamed, K. U. Khalequazzaman, K. M., Shamsuzzaman, A. M. M., Nahar, K. (2008). Plant characteristics, growth and leaf yield of Aloe vera as affected by organic manure in pot culture. *Australian Journal of Crop Science*. 2(3):158-163

Hassan, S. W., Umar, R. A., Ladan, M. J., Nyemike, P., Wasagu, R. S. U., Lawal, M. and Ebbo, A. A. (2007). Nutritive Value, Phytochemical and Antifungal Properties of *Pergularia tomentosa* L. (Asclepiadaceae). *International Journal of Pharmacology* 3.4:334–340.

Heanes, D. L. (1984). Determination of Total Organic Carbon in the Soils by an Improved Chromic Acid Digestion and Spectrophotometric Procedure. *Communication in Soil Science and Plant Analysis* 15:1191-1213.

Hernández-Cruz, L. R., Rodríguez-García, R., Jasso de Rodriguez, D. and Angulo-Sánchez, J. L. (2002). *Aloe vera* Response to Plastic Mulch and Nitrogen. In Janik J. and A Whipkey (Eds). Trends in New Crops and New Uses, ASHS Press. Alexandria: VA, EEUU, Pp. 570–574.

Hes, M, K., Dziedzic, D., Gorecka, A., Jedrusek-Golinska and Gujska, E. (2019). *Aloe vera* (L.) Webb: Natural sources of Antioxidants- A review. Plant foods for human nutrition 74:255-265. https://doi.org/10.1007/s11130-019-00747-51+

International Aloe Science Council (I.A.S.C.). (2002). Aloe scientific primer. (Accessed on 14 June 2007) from http: // www.iasc.org/aloe.html.

International Institute of Tropical Agriculture (I.I.T.A.). (1982). Selected methods for soil and plant analysis. International Institute of Tropical Agriculture, Ibadan, Nigeria. I.I.T.A. Manual series, No. 7. 53-56pp

Lucini, L., Pellizzoni, M. Pellegrino, R. Molinari, G. P. (2015). Phytochemical constituents and in vitro radical scavenging activity of different Aloe species. *Food Chem* 170:501-507. https://doi.org/ 10.1016/j.foodchem.2014.08.034

Mehlich, A. (1984). Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. *Communication in Soil Science and Plant Analysis* 15.12:1409- 1416.

Mengel, K and Kirkby, E. A. (1987). Principles of plant nutrition. International Potash Institutes, 4th Edition Ibl Berne Switzerland 403–414pp.

Moody, J. O., Adebiyi, O. A and Adeniyi, B. A. (2004). Do *Aloe vera* and *Ageratum conyzoides* enhance the anti-microbial activity of traditional medicine soft soaps (Osedudu)? *J. Ethnopharmacol.* 92, 57-60.

Murillo-Amador, B., Luna-Cisneros, M. J., Nieto-Garibay, A., Aguilar-Garcia, M., Troyo Dieguez, E. Garcia-Hernandez J. L. *et al* (2007). Manual para la produccion de Sabila en el Valle del Carrizal. La Paz: Centro de investigaciones Biologicas del Noroeste, 52

Orafidiya, L. O., Agbani, E. O., Oyedele, A. O. Babalola, O.O. Onayemi, O., Aiyedun, F. (2004). The effect of the essential oil of *Ocimum gratissimum Linn* leaf –a preliminary clinical investigation. *International Journal of Aromather* 14:15–21.

Owoade, F. M., Adeoye, G.O, Ade-Oluwa, O.O, Olatunji, O.O. and Lawal, B. A. (2008). Fertilizer trials on performance of *Aloe vera*. *Research on Crops Journal* 9.2:386-389.

Parihar, M. S., Chaudhary, M. Shetty, R and Hemnani, T. (2004). Susceptibility of hippocampus and cerebral cortex to oxidative damage in Streptozotocin treated mice: Prevention by extracts of *Withania somnifera* and *Aloe vera Journal of Clinical Neuroscie*nce 11:397–402.

PCARRD.(Philippine Council for Agriculture and Resources Research and Development). (1983). The Philippines Recommendations for Fertilizer Usage. Los Banos, Laguna. Technical Bulletins series No. 52.

Roughly, (1984). In Somasegaran, P., Hoben, H. J. (1994).eds. Handbook for rhizobia, methods in legume rhizobium technology, Springer-Verlag. New York. Berlin Heidelberg 450pp.

Sakkara, H., Takei, K. and Hirose, N. (2006). Interaction between nitrogen and cytokinin in the regulation of metabolism and development. *Trends in Plant Science* 11:440–448.

Stout, W. S., Fales, L. I., Muller, L. D. Schnabel, R. R. and Weaver, S. R. (2000). Water quality implications of nitrate leaching from intensively grazed pasture swards in the Northeast U.S. *Agricultural Ecosystem and Environment* 77:203–210.

Tejada, M., Benitez, C. and Gonzatez. J. L. (2005). Effects of Application of Two Organomineral Fertilizers on Nutrient Leaching Losses and Wheat crop. *Agronomy Journal* 97:960–967.

Uponi, J. I and Adeoye, G. O. (2000). Soil Testing and Plant Analysis: an overview. In: Agronomy in Nigeria. Department of Agronomy, University of Ibadan. 208-215.

Vazquez, B, Avila, G., Segura, D. Escalante, B. (2004). Anti-inflammatory activity of extracts from *Aloe vera* gel. *Journal of Ethnopharmacology* 55:69–75.

Ved, D. K, Sumy, O. and Archna, S. (2002). Propagation and agrotechnology status of commercially important medicinal plant species of the project area of Andhra Pradesh community forest management project. *Technical Report in the Foundation for Revitalization of Local Health Traditions (FRLHT)* 160pp

Wabuyele, E. E., Sleffen, B. C. Nordal, I. and Newton, N. L. 2006. Distribution, diversity and conservation of the genus Aloe in Kenya. *Journal of East African Natural History* 95.2:213-225.

Yusuf, S., Abdulkarim, A. and Mshelia, D. (2004). The effect of *Aloe vera* (Liliaceae) on gastric acid secretion and acute gastric mucosal injury in rats. *Journal of Ethnopharmacol*ogy 93:33–37.

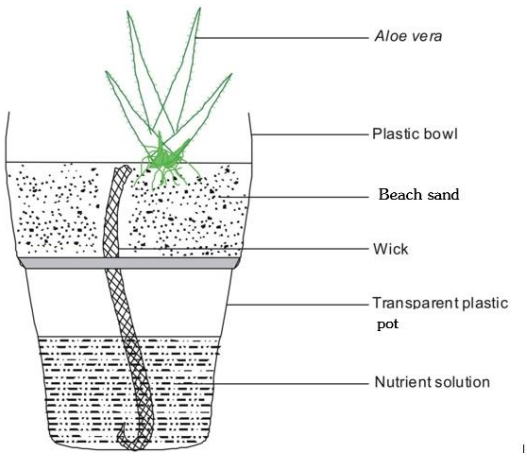


Figure 1: Assemblage of experimental materials in sand culture experiment (The wick supplies water to the sand through capillarity)