



## A Review on the Diverse Uses, Conservation Measures and Agronomic Aspect of *Aloe vera* (L.) Burm.f.

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### Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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### ABSTRACT

**Aims:** This study aims to review the diverse uses of *Aloe vera* (true aloe) as well as the conservation measures and conventional cultivation techniques.

**Study Design:** Best evidence review.

**Place and Duration of Study:** Biomedical Research Centre, Forestry Research Institute of Nigeria.

**Methodology:** Search inputs such as *Aloe vera*, *Aloe barbadensis* in conjunction with the following terms: 'uses', 'overexploitation', 'conservation', 'policy', 'cultivation', 'yield', and 'agronomic

practices' were queried on several scientific databases. Search engines, were also queried for publications covering exploitation, conservation approaches, and cultivation requirements on *Aloe vera*. Other databases such as ScienceDirect and SciFinder were accessed for relevant papers and supplement acquired information after articles (outside the defined scope of the review) were excluded.

**Results:** *Aloe vera* (true aloe) has been engaged particularly for medicinal and cosmetic purposes for thousands of years, and its utilization remains popular till date. *Aloe vera* is popularly valued for its natural products, including nutritional benefits in food, source of nectar for honey bees and nectarivorous birds and horticulture. In this study, several studies demonstrating the botanical characteristics and ecological adaptation of *A. vera* were discussed; agronomic techniques involving the requirements for land preparation, propagation and harvesting were also considered as well as the growth yield of the plant due to different soil types and nutrient applications.

**Conclusion:** For the multifarious uses of *Aloe vera*, adequate policy should be appropriated to regions where this plant is put to industrial uses, over-exploited and threatened. Calcareous and non-calcareous soil have maximum yield on true aloe. *Azotobacter chroococcum* of strain 12 has turned out to be a good growth stimulant bacterium when treated with *A. vera*. Aloe rust and anthracnose disease are known fungal infections, while *Aloe vera* aphid (*Aloephagus myersi*) is an identified pest of the plant.

**Keywords:** *Aloe barbadensis*; overexploitation; policy; cultivation; sustainable; true aloe.

## 1. INTRODUCTION

From time immemorial, there have been major drive in the demand for medicinal plants due to their enormous therapeutic potentials in treating and managing several diseases. Astonishing effectiveness due to the presence of bioactive constituents is evident in the use of these plants of which aloes are arguably the most notable. Pandey and Singh [1] noted that there are over 550 species of *Aloe* grown around the world, however, only two species are grown commercially today; *Aloe vera* and *Aloe aborescens* being the most popular.

*Aloe vera* – a herb belonging to the family Xanthorrhoeaceae and synonymous to *Aloe barbadensis*, commonly called true aloe – is considered an important medicinal plant cultivated in many parts of the world [2,3]. Formerly the species was alternatively placed in the Liliaceae and Aloaceae families. In recent times, the genus *Aloe* is counted between the members of the Xanthorrhoeaceae, sub-family Asphodeloideae [4].

Aluko [5] pointed out that despite being identified as a new plant resource with the most promising prospect and significance in herbal medicine, the potential of true aloe has not been exploited in Africa like it had been in other parts of the world. Ramesh et al. [6] asserted that incorporation of *Aloe vera* into production systems depends on the detailed information of the plants establishment and its agronomic potential.

Hence, the availability and utilization of *Aloe vera* will require information on the most suitable agronomic practices for optimum yield performance.

On the other hand, true aloe has been in use for thousands of years and its utilization is still maintained till date in regions where it is widely valued and exploited for medicinal, nutraceutical, nutritional, cosmetic and horticultural purposes [7]. Now, considering the intensity of aloe exploitation, some pertinent challenges ensue: Are the diverse uses of *A. vera* and man's activities really a concern for the species endangerment? What approach can be taken to sustainably preserve the species? And how can the species be effectively conserved for sustainable utilization? Hence, the purpose of this study is to provide a critical analysis on *A. vera* overexploitation due to its multifarious applications and anthropogenic activities; conservation measures and policy appropriation; and the agronomic requirements for maximum yield.

## 2. METHODOLOGY

Several publishing sites, involving Elsevier and Springer were accessed for books, book chapters, e-books and peer-reviewed journals on *Aloe*. Search inputs such as *Aloe vera*, *Aloe barbadensis* in conjunction with the following terms: 'uses', 'overexploitation', 'conservation', 'policy', 'cultivation', 'yield', and 'agronomic practices' were also included on Google, Google

scholar, OATD, OpenThesis, and ProQuest. Other search engines, involving PdfDrive and Z-Library were queried as well for publications covering exploitation, conservation approaches, and cultivation requirements on *Aloe vera*. The accepted scientific name and appropriate authority of the plant in review (*Aloe vera*) was obtained from PROTA database. During database search, a thorough keywords inquiry relating to the topic was inputted for articles published from 2004 to 2021. The exclusion criteria involved articles published earlier than 2004, and works not related to the inclusionary keywords. Some other scientific databases such as ScienceDirect and SciFinder were consulted to download relevant papers and supplement acquired information after articles (outside the defined scope of the review) were excluded.

### 3. SPECIES EXTINCTION RISK: AN EFFECT OF ANTHROPOGENIC ACTIVITIES

Forty-three (43) species of Aloe, which makes over 7% of the genus were catalogued in the International Union for Conservation of Nature Red List of Threatened Species [7]. Anthropogenic activities – resulting in habitat loss – which involve change of land use (agriculture, mining, urban expansion), energy needs, over-herbivory, and soil erosion was identified to be

the cause of the threat to these species [7]. Extinction risk is high as many more species of Aloe have also been affected by wild collection for traditional uses or natural products but much more by harvesting for the ornamental plant trade as it is believed that traditional harvesting practices rarely result in plant death. Regions where plants are wild-harvested from communal lands and where leaf exudate extraction using the traditional method is not customarily practised have been observed to have higher harvesting rates. Consequently, the targets of these activities are the rare, endemic and utility taxa of Aloe and are, therefore, priorities for conservation [8-9].

### 3.1 *Aloe vera* Conservation and Sustainable Development Goals (SDGs)

The conservation of nature has been identified as one of the easiest ways to sustain the world's economies. Of the seventeen (17) sustainable development goals (SDGs), the first is 'No Poverty' therefore, efforts targeted towards the conservation of *A. vera* will not only reduce poverty as indigenous people often rely on medicinal plants trade for livelihood, but also contribute to sustainable development and prevent potential economic losses as well as improve resilience to climate change [10].



*Aloe vera*. Photo credit: Chris and Kelly, Flickr CC2.0

#### 4. OVER-EXPLOITATION OF *Aloe vera*

In recent times, medicinal plants have been variously demanded and exploited for many reasons. Herbalists collect these plants to satisfy the growing dependence and preference of the people on herbal preparations used in solving their primary health care problems. Due to the over-increasing knowledge and acceptance of the traditional local medicines and, of course elsewhere, there has been an acknowledgeable increase in the use into which these medicinal

plants are put. Again, as cases of disease infestation continue to rise and the cost of western medication appears unaffordable, this pattern of dependence of the people on these plants continues to rise. Many *Aloe* species are valued from ancient times till this present era for the healing properties associated with the leaf tissues, a factor that has led to over-exploitation of natural populations and endangerment of these species, especially *Aloe vera*. The therapeutic multifarity of this substantial plant is presented in Table 1.

**Table 1. Various ways in which *Aloe vera* is being exploited for its therapeutic values**

S/N	Therapeutic Values	Description	Reference
1.	General medicinal use	<i>Aloe vera</i> gel is engaged in the treatment of dropsy carbuncles, sciatica, debility, diabetes, immune-system deficiencies, digestive and abdominal disorders. It is also used in hepatopathy and skin care as well as astringent and appetite stimulant.	[11-14]
2.	Antioxidant/detoxifying properties	An excellent example of a functional food that protects the body from oxidative stress is <i>Aloe vera</i> . The juice cleanses the body system and provides it with an amazingly rich cocktail of vitamins, minerals and trace elements, which helps to deal with the stresses and strains arising from daily environmental pollution and the junk foods we eat.	[15-19]
3.	Anti-inflammatory properties	Pain and inflammation in weakened or aged joints are assuaged when joint muscles get strengthened. <i>Aloe vera</i> strengthens the regeneration of body cells and joint flexibility. Aspirin-like compound present in true aloe is responsible for anti-inflammatory properties.	[20-23]
4.	Immunity building	<i>Aloe vera</i> is great for those who have chronic immune disorders. The polysaccharides in the juice stimulate macrophages, the white blood cells that fight viruses.	[24-25]
5.	Cosmetic/skin protection	Pimples are treated with skin tonic made from aloin and its gel. The aloe sugars are also used in moisturizing preparations to manage flaky scalp and skin in dry and unpleasant weather condition. Metallothionein, a skin-generated antioxidant protein, is found in <i>Aloe vera</i> gel. This protein scavenges hydroxyl radicals and prevents suppression of superoxide dismutase and glutathione peroxidase in the skin.	[14,26,27]
6.	Antiseptic	The presence of six antiseptic agents in <i>Aloe vera</i> : cinnamonic acid, lupeol, phenols, salicylic acid, sulphur and urea nitrogen induces its antiseptic property. These compounds inhibit the activity of bacteria, fungi and viruses.	[28,29]
7.	Anti-diabetic	Five phytosterols found in <i>A. vera</i> , 24-ethyl-lophenol, 24-methylenecycloartanol, 24-methyllophenol, cycloartanol and lophenol proved effective in type-2 diabetic mice.	[30,31]

8.	Antitumor activity	Increase in the proliferation of normal human dermal cells as well as antitumor and antiulcer effects have been reportedly attributed to the glycoproteins present in <i>Aloe vera</i> gel. An induction of glutathione S-transferase and an inhibition of the tumor-promoting effects of phorbol myristic acetate, which suggest a possible benefit of using aloe gel in cancer chemoprevention has also been reported.	[32,33]
9.	Laxative effects	Increase in intestinal water content and intestinal peristalsis as well as the induction of mucus secretion has been reportedly attributed to anthraquinones present in aloe latex.	[34]
10.	Antiviral activity	The infectivity of herpes simplex virus Type I and Type II, including varicella zoster virus, influenza virus, and pseudorabies virus was shown to be incapacitated by a purified sample of aloe emodin.	[35-38]
11.	Antibiotic	Aloe gel inhibited the growth of <i>Trichophyton mentagrophytes</i> , while the leaf possesses inhibitory effects on both <i>Pseudomonas aeruginosa</i> and <i>Candida albicans</i> . The saponins perform strongly as anti-microbial against bacteria, viruses, fungi and yeasts.	[19,39-42]
12	Wound-healing property	Mannose-6-phosphate found in <i>Aloe vera</i> gel has been shown to have wound-healing effect against first to second degree burns. Aloe administration influence collagen composition (more type III) and increased collagen cross-linking for wound contraction and improving breaking strength. It also increases synthesis of hyaluronic acid and dermatan sulfate in the granulation tissue of a healing wound.	[43,44]

#### 4.1 Need for Conservative Measures and Policy Appropriation

As much as aloes are popularly valued for their natural products [9,45], in terms of their medicinal significance [46], they also serve nutritional benefits in food [9,47]; as important source of nectar for honey bees (*Apis mellifera*) and nectarivorous birds, which is characteristic of the flowering species during the dry season [46,48]; horticultural [9]; and cosmetic purposes [49]. Consequently, twenty-one (21) species of *Aloe* threatened by extinction are listed on CITES Appendix I, prohibiting all international trade for commercial purposes [50]. The diversity of the genus and the many ways in which true aloe is valued around the world highlight the need for effective conservation measures and policy approaches for the species to be used sustainably [9].

Conservation is the fundamental objective of succulent plant collectors' societies as it is clear that harvesters of succulent plant kinds play critical role in the sustainable future of *Aloe* spp. as much as the ex-situ preservation of species

diversity. The interest groups – involving the International Organization for Succulent Plant Study, British Cactus and Succulent Society, Cactus and Succulent Society of America, the Succulent Society of South Africa, among others – promote ethical and lawful harvesting practices that are compliant with both the Convention on Biological Diversity (CBD) and legal requirements. This case is not specific only to *Aloe* spp., yet influential parties are well placed to continue fostering demands for plant specimens sourced in ways that uphold the objectives of the CBD [9,51].

#### 4.2 Policy Appropriation: An Effort towards *Aloe* Spp. Conservation in Africa

Effective policy is key to support conservation and natural resources maximization. There are several reports on the efforts towards the conservation of many species of *Aloe* by means of establishing certain policies in some countries. Grace [9] pointed out that sustainable harvesting, in the instance of *Aloe* spp., is greatly dependent on the stakeholders in the natural products and

horticultural industries. Grace [9] reported that the threats and conservation status of *Aloe* spp. in Africa, especially South Africa are arguably the most well-studied. In this study, the policy towards the conservation of *Aloe* species native to some countries such as Kenya, South Africa and Nigeria are considered.

In Kenya, Wabuyele and Kyalo [52] reported that *Aloe* Management Units (protocols for sustainable wild-collection on a commercial scale) have been developed for *A. calidophila* Reynolds, *A. rivae* Baker, *A. scabrifolia* and *A. secundiflora* but the full implementation was yet unactualised. Wild-collection of *Aloe* spp. is illegal and therefore not reflected in export statistics for Kenya, but is known to support a considerable trade in the leaf exudate. *A. macrosiphon* Baker and *A. ukambensis* Reynolds are the East African taxa identified as the most suitable for the natural products industry and large-scale propagation. *A. secundiflora*, *A. scabrifolia* and possibly *A. turkanensis*, a possible misidentification of *A. scabrifolia* are of particular concern for sustainable management [53].

In South Africa, the *A. ferox* industry is among the local bioresource industries covered by recent legislative developments in bioprospecting, access and benefit-sharing regulations within the National Environmental Management Biodiversity Act (NEMBA) [9]. The alignment of national laws with international agreements involving Convention on Biological Diversity (CBD) and Convention on International Trade in Endangered Species (CITES) are provided for in the new legal framework [50], as well as potentially positive outcomes for stakeholders at all levels in the *A. ferox* industry. This is achieved by the protection of traditional knowledge holders, sustainable resource management, best practice in processing and the equitable distribution of benefits [9]. However, at least one development initiative based on *A. ferox* in the Eastern Cape has been affected by practical shortfalls in the implementation of the new legislature [10,50]. South Africa is among a small proportion of CBD member countries to have ratified the agreement in national law. To measure progressive successes, an assessment within the context of the new laws will be necessary, with particular attention to the distinction between the wild-collection of *A. ferox* from communal or privately-owned lands, and to identify changes still required of the industry. Developments in the *A. ferox* industry will undoubtedly be relevant to emerging aloe-based

industries elsewhere in the range of *Aloe* spp. [9, 50].

Notable *Aloe* species native to Nigeria are *A. buettneri*, *A. vera* and *A. schweinfurthii*. Among these plant taxa, *A. vera* is widely engaged for various uses. And there is little or no data about the conservation strategy. Based on poor land use management resulting from anthropogenic activities, there may be serious threat concern for *A. buettneri* and *A. schweinfurthii*, which are rare in the wild and not popular for domestic cultivation, unlike *A. vera*, in Nigeria. This verity concerning *Aloe* spp. in the country agrees with the account of Grace [9] who observed that "CITES protects all species of *Aloe* except *A. vera*. To reflect the species being widely domesticated, it was removed from the CITES Appendices in 1985, in spite of being perhaps no longer existent in the wild. However, there is little extensive cultivation of true aloe in Nigeria and the species are dying out in flower vases in some homes due to its overuse and inadequate understanding of the agronomic techniques. The species originates from the Arabian Peninsula but there are no records of the species being seen in its natural habitat recently. To encourage equitable sharing of benefits for workers and sustainable harvesting, the Aloe Tappers Association was established in South Africa in the 1980s and the Kenya Aloe Working Group in the 1990s. Unlike Benin, Kenya, Senegal, South Africa, Niger, among other African countries, Nigeria is not among the parties to the Convention on Biological Diversity (CBD). The CBD is aimed at the institution of sustainable use of biological diversity components, and equitable sharing of benefits arising from genetic resources.

Policy with respect to threatened or over-exploited species undoubtedly drives sustainable conservation, which is unachievable without conscious cultivation and well-rounded agronomic practices. As a matter of fact, Manvitha and Bidya [54] pointed out that *Aloe vera* cultivation has acquired outstanding commercial value for cosmetics and medicinal products. And it is important to note that farmers, on a regular basis, encounter challenges such as low ground water level, lack of rain, soil degradation, and so forth.

## 5. BOTANICAL AND ECOLOGICAL NATURE OF *Aloe vera*

*Aloe vera* has been widely studied for its flora characteristics and salient ecological adaptation.

Christaki and Paneri [55] described it as a perennial succulent xerophyte with thick fleshy leaves that permit the storage of water in the form of the gel. The gel represents approximately 70-80 % by weight of the whole leaf extract. The plant grows to about 30 to 50 cm in length and 10 cm in breadth in the matured plant in a typical rosette pattern with rhizomes that easily spread from basal offshoots colonizing extensive areas and outcompeting thereby displacing other species including native vegetation [56-58]. *Aloe vera* is commonly called aloe, burn plant, elephant's gall, lily of the desert and true aloe. It is cactus-like having dagger-shaped, fleshy, marginated, spiny, tapering leaves that contain a clear glutinous gel. It is a short-stemmed or stemless herb with height up to 80-100 cm, spreading by offsets and root sprouts. The leaves are green to grey-green or lime coloured, with a serrated margin, thick and fleshy due to water storage tissue in the leaves to survive in dry areas of low rainfall.

*Aloe vera* prefers a high intensity of sunlight and requires little water for its establishment. It prefers hot humid regions with mean annual temperatures within the range 19-27 °C but can tolerate temperatures ranging from 10 °C to 35 °C. The plant is adapted to areas with mean annual rainfall in the range 700 mm to 3000 mm and it is highly sensitive to water stagnation therefore, proper drainage is important for its establishment [59]. It is striking to note that *A. vera* plant can survive for many months when uprooted from the soil. "It has distinctive characteristics of which it can survive for more than 7 years without water. This is as a result of the plant undergoing Crassulacean acid metabolism (CAM) metabolic pathway for conserving water within the parenchymatous tissues to withstand drought conditions" [58]. The natural range of *Aloe vera* is still very much unclear as the species has been widely cultivated in different regions. Most botanists agree that historical evidence suggests that *Aloe vera* originates in the warm, dry climate of Africa. It is found growing in the sub-tropical and tropical locations including South America and Caribbean as well as the Mediterranean shrub lands, dry forests, urban bush lands, riparian areas, sand dunes and other sandy coastal habitats [60-61].

Each part of aloe leaf yields different substances with distinct constituents and therapeutic composition. The outer pericyclic tubules, which exist just below the cutinized leaf epidermis

(outer green rind), exude a bitter yellow sap. The gel (inner glutinous pulp), which stretches along the leaf centre is composed of 96 % water while 75 known substances, including amino acids, calcium, enzymes, and vitamins (A, B, C, E) are contained in the remaining 4 % [13].

## 6. SOIL REQUIREMENTS

*Aloe vera* is grown under different types of soils ranging from marginal to sub marginal soils but preferably it grows best on well drained sandy or loamy soils with high organic matter. *Aloe vera* can also tolerate poor, saline and /or sodic soil [62-64]. The plants have tendency to tolerate high pH with high Na and K salts.

### 6.1 Nature of Different Soil Types in Relation to *A. vera* Growth Yield

Seven (7) different soils of Bangladesh were studied for their effect on the growth and leaf biomass yield of *A. vera*. The observed physicochemical properties for these soils in terms of colour, texture, pH, organic matter, and total nitrogen are: reddish, clay, 5.2, 1.58 %, and 0.09 % respectively for acid soil; light grey, clay-loam, 7.5, 1.4, and 0.07%, respectively for calcareous soil; light grey, sandy-clay-loam, 6.7, 1.83 %, and 0.12 % respectively for non-calcareous soil; light grey, loam, 7.0, 0.88 %, and 0.05 respectively for charland soil; light grey, clay, 7.5, 1.97 %, and 0.11 % respectively for saline soil; blackish, clay-loam, 5.7, 16.40 % and 0.95 % respectively for peat soil; and light grey, clay, 3.8, 14.04 % and 2.45 % respectively for acid sulphate soil [64].

#### 6.1.1 Effect of the soil types on plant height and number of leaves

Chowdhury et al. [64] showed that the height of *A. vera* plant at harvest was significantly influenced by soil types. The plant grown in non-calcareous soil recorded the highest height (44.03 cm), followed by calcareous soil (41.73 cm) and acid soil (40.37cm). The plant grown in acid sulphate soil recorded the lowest height (23.17 cm). The authors also observed that the different soil types had significant influence on the leaves count of individual plant at harvest. The plant grown in non-calcareous soil produced highest count of leaves per plant (12.67), followed by acid soil (11.33) and calcareous soil (10.89), while the least number of leaves (4.00) was found in peat soil. The authors noted that good soil texture, moderate pH (6.7 – 7.5), less

moisture-retention capacity and higher nutrient contents might result to better performance of non-calcareous and calcareous soils compared to other soils. Similarly, BARC [65] reported that better yield could be obtained as a result of the reaction of acid strength in reaction with moderate measure of organic matter and low water-retention capacity, which is typical of acid soil with a pH < 7 (and of course, calcareous and non-calcareous soil).

### 6.1.2 Effect of the soil types on leaf area and leaf fresh weight

Chowdhury et al. [64] investigated the effect of soil types on leaf area and leaf fresh weight of *Aloe vera* plants and found that different soil types significantly affected the mean leaf area of each plant. The plant grown in non-calcareous soil recorded the maximum leaf area and leaf fresh weight (262.70 cm<sup>2</sup> and 1948 g/plant respectively), while the least leaf area and leaf fresh weight (144.38 cm<sup>2</sup> and 233 g/plant respectively) were measured in the plant grown in acid sulphate soil. The authors inferred that a very low yield of *A. vera* in acid sulphate soil could be caused by the insignificant pH value (3.8) which in turn brings about reduction in available nutrient and in peat soil, a huge amount of organic matter that can result in nutrient toxicity. The plant grown in calcareous soil, as observed by same authors, recorded the highest fresh leaf gel weight (907 g/plant), followed by that in acid soil (880 g/plant) and non-calcareous soil (859 g/plant). However, the plant grown in peat soil recorded the lowest fresh gel weight (192 g/plant). Khan et al. [66] accordingly attributed abysmal performance of soil to its huge quantity of organic matter (typical of peat soil > 20 %) and water saturated environment.

### 6.1.3 Effect of the soil types on dry leaf weight

The dry weight of *A. vera* leaf grown in the different soils was also evaluated by Chowdhury et al. [64] and the maximum value (136.0 g/plant) was obtained in calcareous soil, followed by acid soil (133.4 g/plant) and non-calcareous (132.3 g/plant) soil. The plant grown in acid sulphate soil recorded the minimum dry weight (16.3g/plant).

Chowdhury et al. [64] observed best performance with respect to leaf number, leaf area, leaf fresh weight, and plant height of *A. vera* grown in calcareous soil, followed by those of non-calcareous and acid soils. The poorest

performance was, however, observed in acid sulphate soil. The authors revealed that some environmental factors such as saline tidal flooding, tidal bores and probability of cyclone storms severely limit the potential of the acid sulphate soils for crop production. Apart from the abysmal pH value (3.9) that characterized the poorest performance of *A. vera* plant in acid sulphate soil iron sulphides in the soil is reported to be another cause. Khan et al. [66] pointed out that the resulting chemical reaction between SO<sub>4</sub><sup>2-</sup> in sea water and land sediments containing oxides, when sea level rise inundates land, produces sulphuric acid for which acid sulphate soil is coined. Mukit [67] also noted that deficiency of phosphorous and toxicity of iron and aluminium are the major constraints for crop cultivation in acid sulphate soil.

Since calcareous and non-calcareous soils are mostly used in Bangladesh for growing cereals, pulses, cash crop like sugarcane, fruits, etc., it is suggested from the overall results of Chowdhury et al. [64] that farmers could grow *A. vera* either in calcareous or acid soils. Acid soil could also be a good option for cultivating this important medicinal crop considering the middle-income economic condition of the country, and many African countries alike, including Nigeria.

## 7. LAND PREPARATION AND PROPAGATION

The soil in which true aloe must be positioned does not require much deep as the root system of the plant does not penetrate below 20-30 cm depending upon the soil type and agro-climatic condition, about 1-2 ploughing and laddering are done to make the soil weed-free and friable. Field may be divided into suitable sized plots (10-15 m by 3 m) considering the slope and source of irrigation [54,64].

*Aloe vera* is propagated vegetatively by using root suckers or rhizome cuttings of a new growth. About 15-18 cm long root suckers are planted by keeping two-third portions underneath the soil. Plant population of 15 000 root suckers with spacing of 60 cm by 60 cm is required for plantation establishment [68]. Irrigation is important at certain stages during plant cultivation in order to achieve good crop yield. The first irrigation should be done just after planting of the suckers. It requires about 150 ml of water monthly for good quality leaf weighing approximately 1 kg [68]. Subsequently, 2-3 irrigations should be done until the plants are



well established. Depending on the availability of water, light irrigation should be done after harvesting of the leaves [69].

## 8. NUTRIENTS APPLICATION

Nitrogen is an essential nutrient element needed during cultivation of *Aloe vera* due to its importance in the conformation of photosynthetically active pigments that affect the development and yield [70,71]. In *Aloe vera* plantation, organic manure such as cow dung with urea is equivalent in effect to mineral fertilization [3]. For instance, before land preparation, about 8-10 tonnes of farm yard manure per hectare are applied, before the last ploughing, 35 kg N, 70 kg P<sub>2</sub>O<sub>5</sub> and 70 kg K<sub>2</sub>O/ha are added. About 350-400 kg neem cake/ha should be applied to prevent termites infestation. However, mineral nitrogen fertilization increases length, number and fresh weight of leaves [72]. Nitric sources of nitrogen associated with ammonium in low concentration have been reported to promote the growth of the species positively [70].

### 8.1 Effects of the Different Levels of Bio-Fertilizers on the Growth Yield of *Aloe vera*

Aeini et al. [72] studied the effect of seven different growth-stimulant bacteria in greenhouse condition and revealed that *A. vera* treatments inoculated with *Azotobacter chroococcum* of strain 12 was more effective on the plant quantitative traits in comparison with other fertilizers, which involved bacteria inoculation using *Pseudomonas fluorescens* of Strain 41, *Azospirillum brasilense* and four different levels of their combination.

## 9. PEST AND DISEASES

Although there are limited scholarly articles on the pests and diseases of *Aloe vera*, some common infections of the plant have been described. Aloe rust caused by *Phakopsora pachyrhizi* is a fungal infection that causes the appearance of pale-yellow spots that expand and turn brown on the leaves; orange spore masses may also be found on underside of the leaves. These may eventually cause such leaves to fall off. The fungus is commonly found in areas with cool temperature and high humidity, and is said to require no treatment. Anthracnose disease is also a fungal infection caused by *Colletotrichum gloeosporioides*. This disease is favoured and

easily spread in warm, wet weather especially water splash. It is characterized by the development of small, round to oval dark green water-soaked spots that later become reddish brown to brown round lesions that join together to form big necrotic area. Suitable fungicides are often required for treatment. *Fusarium spp* is another fungus that attack the base of *Aloe vera*, causing it to change colour to reddish brown and black and eventually rotting. Cold, damp conditions are favourable for the emergence of this disease and pieces of the plant may be saved when cuttings are made above the rotten stem. Bacterial soft rot, caused by *Pectobacterium chrysanthemi* is a serious disease of *A. vera* that is often characterized by watery, rotting, wilting and collapsing young leaves. This bacterium survives in plant debris on the field, and the disease emergence is favoured by hot, wet weather and may worsen with over-watering of the plant. *Aloe vera* aphid (*Aloephagus myersi*) is an insect pest that secrete honeydew resulting in mold development. Severe infestation causes slow growth and stunting of the plant. This pest may be organically controlled by the use of insecticidal soap [68,73-74]. Scientific studies that will focus on properly identifying the different pests and diseases of *A. vera* are recommended.

## 10. HARVESTING

Harvesting of *Aloe vera* leaves is usually done after 7-8 months of planting where the outermost leaves are harvested by pulling each leaf away from the plant stalk and cutting at the white base. Optimum care should be taken to prevent damage to the outer rind and to maintain the seal at the base of the leaf in order to prevent microbial contamination. It has been stated that the best period for harvest is between October and November. For maximum yield the second year is the most preferred [54].

## 11. CONCLUSION

For the multifarious uses of *Aloe vera* encompassing food, medicinal, cosmetic and horticultural purposes – a cause for endangerment concern – effective conservation measure is necessary for the plant sustainability. Adequate policy should be appropriated to regions where this plant is put to industrial uses, over-exploited and threatened. Cultivation is key factor in conserving true aloe. Despite the wide applications and over-exploitation of *A. vera*, its survivable resilience is evident in the fact that it

possesses spectacular botanical characteristic, which impacts its adaptability to harsh condition or parched environment. Calcareous and non-calcareous soil have been proved to yield maximal growth for *A. vera* while acid soil could also be a good option, especially in middle-income countries where calcareous soil is unaffordable. Essential nutrient for the plant cultivation is nitrogen; organic manure such as cow dung is good as well. *Azotobacter chroococcum* of strain 12 has turned out to be a good growth stimulant bacterium when treated with *A. vera*. Aloe rust and anthracnose disease are known fungal infections caused by *Phakopsora pachyrhizi* and *Colletotrichum gloeosporioides*, respectively. Another disease of aloe is a bacterial infection caused by *Pectobacterium chrysanthemi*. *Aloe vera* aphid (*Aloephagus myersi*) has been identified to affect the plant. Harvesting is commonly done after 7-8 months of planting in the best period between October and November.

## CONSENT

It is not applicable.

## ETHICAL APPROVAL

It is not applicable.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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