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An Updated Overview on *Aloe vera* (L.) Burm. f.

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ABSTRACT

Aloe vera (L.) Burm. f is a succulent shrubby perennial of the family Asphodelaceae (commonly known as 'Natural healer', 'Lily of the desert', 'Plant of immortality', 'Miracle plant', 'The Wand of Heaven', etc.) with immense therapeutic uses not withstanding its potential significance in cosmetic and food industries. The plant is the source of two products, gel and latex (commercially aloe products are pills, jellies and creams, drinks, liquid, sprays, ointments and lotions) obtained from its fleshy leaves. This unique plant also belongs to a larger plant family, the 'Xeroids'. Considering the pharmacological and other potential uses of *A. vera*, an updated overview is being conducted on the species involving all essential aspects to provide necessary information to researchers for effective utilization of the species in human welfare.

Keywords: aloe gel, an overview
Abbreviations: **AAP**, acetaminophen; **AG**, aloe gel; **AGE**, *Aloe vera* leaf gel extract; **AL**, aloe whole leaf decolorized gel; **CMA**, chromomycin A_3; **CD**, cyclin-dependent; **DAPI**, 4',6-diamidino-2-phenylindole; **DMBA**, 7,12-dimethylbenz(a)anthracene; **DREB**, dehydration responsive element-binding factor; **GAG**, glycosamino glycan; **GLUT**, glucose transporter; **GUS**, β-glucuronidase; **HPMC**, hydroxypropyl methylcellulose; **IR**, infra-red; **NHEK(F)**, normal human epidermal keratinocytes; **NMDA**, *N*-methyl-D-aspartic acid; **OLP**, oral lichen planus; **ORAC**, oxygen radical absorbance capacity; **RACE**, rapid amplification of cDNA ends; **RGCs**, retina ganglion cells; **TBARS**, thiobarbituric acid reactive substances

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INTRODUCTION

Aloe vera (L.) Burm. f. is a succulent, shrubby, perennial (Family: Asphodelaceae, previously under the family Liliaceae; commonly known as - "Natural healer", "Lily of the desert", "Plant of immortality", "Nature's Own First Aid Kit" – source FAO; "The wand of Heaven" – called by American Indians, "Miracle plant" – Atherton 1998), possessing immense therapeutic uses. This unique plant also belongs to a larger plant family, the "Xeroids". The name aloe is derived from the Arabic "alloeh" or "halal" meaning bitter shiny substance (Joseph and Raj 2010). The plant is the source of two products, gel and latex, which are obtained from its fleshy leaves (Boudreau and Beland 2006).

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Review

A. vera leaves secretes two types of exudates, one of which is a bitter (bitterness is due to the presence of aloin, aloe-emodin and related compounds) reddish-yellow juice (present in the pericyclic cells located under strongly cutinized epidermis) generally used for laxative purposes and in dried form; while, the other exudate is a transparent mucilaginous gel produced by the thin walled tubular cells (parenchymatous) in the inner central zone of the leaves (Joseph and Raj 2010). Aloe gel is referred to as AG and it possesses diverse range of pharmacological properties (Ni *et al.* 2004; Talmadge *et al.* 2004; Dutta Gupta 2010). Although an adequate number of review articles on *A. vera* on specific aspects like gel chemistry, biological activity, post harvest gel processing, cosmetic attributes, antimicrobial activities amongst others (Klein and Penneys 1988; Atherton 1998; Vogler and Ernst 1999; Choi and Chung 2003; Boudreaua and Belanda 2006; Hamman 2008; Dutta Gupta 2010) are documented in the literature, but considering the pharmacological and other potential uses of the species (a crop whose potential is yet to be explored, despite being identified as a 'new plant resource with the most promising prospects' in the world) an updated overview is conducted involving nearly all essential aspects to provide necessary information to researchers looking to eugenize the species for proper utilization in human benefits.

Synonyms

Aloe abyssinica Lam., *A. barbadensis* Mill., *A. chinensis* Baker, *A. flava* Pers., *A. indica* Royle, *A. littoralis* Koen. ex Baker, *A. officinalis* Forssk., *A. perfoliata* L. var. *vera* L., *A. vulgaris* Lam..

Common names

Afrikaans: Aalwee, Aalwyn; Arabic: الألـوة , نبـات الألـوه; Bengali: Ghrita kumari, Kumari; Chinese:龙舌兰; Danish: Lægealoe; Dutch: Aloë; English: Barbados aloe, Coastal aloe, Curaçao aloe, Indian aloe, Jaffarabad aloe, Medicinal aloe, Mediterranean aloe, Star cactus, True aloe, West Indian aloe; Finnish: Lääkeaaloe; French: Aloès, Aloès vulgaire; German: Echte Aloe; Hindi: Guar patha, Ghikanvar; Italian: Aloe di Curacao, Aloe delle Barbados, Aloe mediterranea, Aloe vera, Legno aloe; Japanese: アロエ Aroe; Kannada: Lolisara; Malay: Pohon gaharu; Malayalam: Kumari; Marathi: Korphad; Nepalese: Ghiu kumara; Oriya: Kumari; Persian: داربو; Polish: Aloes zwyczajny; Portuguese: Aloés, Aloé vera, Babosa (Brazil), Aloés de Barbados, Erva-babosa, Azebre Vegetal; Russian: Алоэ Aloe, Алое настоящее Aloe nastojaščee, Алоэ Вера Aloe vera; Sanskrit: Ghrita kumari, Kumari; Serbian: Aloja; Shona: Gavakava; Spanish: Acíbar, Aloe, Flor do deserto (Argentina), Loto do deserto (Argentina), Linláloe, Maguey morado, Penca sábila (Colombia), Pitera amarelo (Argentina), Sábila (Mexico), Sábila do penca (Argentina), Sávila, Toots amarelo (Argentina), Zábila, Zábila dos toots (Argentina); Swedish: Aloe, Barbados aloe; Tamil: Chirukuttali; Telugu: Chinna kalabanda; Thai: หางตะเข้ Hang ta khe, ว่านไฟไหม้ Wan fai mai, ว่านหางจระเข้ Wan hang chora khe; Turkish: Ödağacı, Sarısabır, Sarýsabýr; Vietnamese: Cây aloe vera, Cây Lô Hội, Cây Nha Đam.

Distribution

The genus *Aloe* comprising of (22 species - CITES) more than 360 species and sub-species are reported from subtropical as well as temperate parts of the world. *A. vera* is indigenous to Africa and to Mediterranean countries. It is reported to grow wild on the islands of Cyprus, Malta, Sicily, Canary, Cape Verde and arid tracts of India. Kenya (57 species reported of which 80% are found in the rangelands) possesses the greatest *Aloe* diversity amongst East African countries. The species is unknown in South Africa until the 1980's. *A. vera* is known as medicinal aloe in South Africa and about 16 products are developed by different pharmaceutical companies and one of the leading exporters. The common species of South Africa is *A. striata*. Between 1994 and 2003, South Africa exported 155 species of *Aloe* (Knapp 2006). The species may also be cultivated in drought-prone areas. In India the species grows wild along the coast of Southern India. China, USA, Mexico and some of the Latin American countries are the chief producers and exporters of aloe products (Knapp 2006). A turnover of almost $2.2 billion in 2008 is reported for *A. vera* in the USA (Forever Living Products Distributor). *Aloe* plants may also be found in temperate zones as cultivated crops or ornamentals, but the species should be protected from freezing water.

Plant description

A. vera is a stemless or very short stemmed, succulent, 60-100 cm tall, perennial, spresding by offsets. The leaves are lanceolate, spirally arranged, rosette, thick and fleshy, green to grey-green with white flecks on the upper and lower stem surfaces (Yates 2002); leaf margin serrated with small white teeth. Mature leaf is 7-10 cm across at the base, weighing 1.5-2.0 kg. Roots are fibrous, fleshy. The flowers are produced in summer on a spike up to 90 cm tall, each flower pendulous, with a yellow tubular corolla 2–3 cm long (Yates 2002).

Released varieties in India

The National Bureau of Plant Genetic Resources (NBPGR) and Indian Council of Agricultural Research (ICAR) released IC 111271, IC 111269, IC 111280 and IC 111273 varieties with high aloin (20.7-22.8%) content for cultivation (Maiti and Chandra 2002). The Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow, also released AL-1 for commercial cultivation (Maiti and Chandra 2002). Leaves and side suckers of AL-I are sold and four harvests of each plant can be made.

Cultivation

1. Climate

A. vera possesses a wide range of adaptability and can grow in different climatic conditions like dry, humid as well as extreme cold and even on the poorest of soils (Das and Chattopadhay 2004). The plant flourishes well on dry sand soil with lower annual rainfall of 50 to 300 mm and needs to be protected from frost and low winter temperature. The best time of cultivation is form March to June, and the species should be provided with protective irrigation (Farooqi and Sreeramu 2004). In India, it grows best in Rajasthan, Gujarat, Madhya Pradesh and Maharashtra (Maiti and Chandra 2002).

2. Soil

The species can grow in different types of soils namely, sandy coastal soils, loamy soils, light soils, medium fertile heavy soils (black cotton soils) etc. but highly sensitive to water logged conditions. The plant can tolerate high pH with high Na and K salts. The species is reported to grow well in coarse sandy loam soils with moderate fertility and with pH ranging from 7.0 to 8.5 (Maiti and Chandra 2002). The root system of the plant species is shallow and does not penetrate deep into the soil (Das and Chattopadhay 2004).

3. Land preparation and planting

Soil distribution should not be too deep and depending on soil types and agro-climatic condition, 1-2 ploughing followed by levelling may be done. Ridges and furrows are formed at 45 cm apart. Adding of cow-dung manure (25 t/ha) to soil is recommended during land preparation (Farooqi and Sreeramu 2004). About 15-18 cm long root-

suckers or rhizome cuttings are planted by keeping two third portion under the ground and nearly 15,000 pulps are required for plantation for one hectare with plant-to-plant and row-to-row, 60 cm × 60 cm spacing (Das and Chattopadhay 2004). However, Maity and Chandra (2002) recommended 25,000 to 34,000 suckers/ha. In West Bengal (Narendrapur Ram Krisna Mission, Medicinal Plant Garden, Government of West Bengal (India), *A. vera* is planted 61 × 61 cm apart and about 21,600 suckers are needed in one acre of land. Weeding at regular intervals followed by light hoeing is essential for growth of *Aloe* plantations.

4. Manures

Aloe is raised as organic crop and only Farm Yard Manure (12-15 t/ha) is applied and in standing crop cow-dung is provided to soil (Das and Chattopadhay 2004). Vermicompost (2.5 t/ha) and wood ash may also be applied in the pits during plantation ensuring proper plant growth (Maiti and Chandra 2002). Ammonium nitrate can be added as an additional annual supplement for nutritional value during land preparations for optimum yield (Das and Chattopadhay 2004).

5. Irrigation

The species is cultivated both under irrigated and rainfed conditions and provision of irrigation immediately after planting and during summer season ensure good yield. For proper growth about 4 to 6 irrigations/year is enough. Light irrigation is recommended after each picking of leaves (Maiti and Chandra 2002).

6. Plant protection

Mealy bug, termite and fungus causing anthracnose and leaf spots are reported to affect yield and quality of gel adversely but spraying recommended fungicides can control fungal infections; while, light irrigation can manage termite problem (Maiti and Chandra 2002, Farooqi and Sreeramu 2004). Diseased plants and dried flower stalks must be removed regularly.

7. Intercropping

Suitable leguminous or less competitive intercrops like cluster bean, groundnut, sesame, isabgol, coriander, cumin amongst others may be planted in the interspaces under arid and semi-arid conditions to generate additional income (Maiti and Chandra 2002).

8. Harvesting and yield

Commercial yield in *Aloe* plantation is from second to fifth year of transplantation. Large healthy outer leaves at the bottom of the plant are harvested by cutting close to the base of the plant at the angle, and generally 4 harvests are taken in a year in the morning and/or evening. On an average 15-20 t/ha fresh leaf is harvested; however, well managed irrigated crop can give up to 30-35 t/ha fresh leaf. Suckers from about 50% of the plant can be sold annually (Maiti and Chandra 2002). Das and Chattopadhay (2004) reported that on an average organically grown *Aloe* yields about 12 t/ha on fresh weight basis.

9. Post-harvest management and processing

The juice (colorless or yellow) from cut leaves (excluding one inch of leaf base, the tapering point of the leaf top, and the spines on the margins) are allowed to drain into vessels, concentrated by evaporation either spontaneously or frequently by boiling (color: dark brown). Sun dried or concentrated aloe juice over a fire gives an amorphous, opaque, waxy extract called 'hepatic' or 'livery' aloe. However, if the juice is concentrated rapidly over a strong fire, the product obtained on cooling is amorphous and is called 'glassy' or 'vitreous' aloe. The mucilaginous pulp is scraped out and stirred in a blender to make homogeneous mixture, strained with the help of a muslin cloth, filtered, precipitated from extract by slowly adding acetone while stirring and the whole content is kept overnight and the gel is isolated following centrifugation. *Aloe* should be processed within few hours of harvest to prevent oxidation (Maiti and Chandra 2002).

Gulia *et al.* (2010) reported that the percent powder yield of *A. vera* leaves (leaves dried in hot air oven and powdered) is found to be 2.60, 2.60, 2.55 and 2.52 at 50, 60, 70 and 80°C, respectively. Powdered samples are with pH (1% solution) of 3.51, 3.59, 3.52 and 3.53 with the rise of dry temperature in the selected range. Statistically, yield and pH indicated no significant differences ($P < 0.5$) due to drying temperature variation. The HPLC chromatogram obtained for the sample dried at 80°C shows that as the temperature increase from 50 to 80°C, aloin content decrease from 10.6 to 1.7 ppm.

10. Technical guidance

The Central Institute for Medicinal and Aromatic Plants (CIMAP), the National Research Centre for Medicinal and Aromatic Plants, State Agricultural Universities, Regional Research Laboratories etc. of India provides technical guidance to *Aloe* planters.

11. Marketing and export

Aloe gel, juice and concentrate are traded through different commercial pharmaceutical companies (Xena Bio Herbals Pvt. Ltd., Boom Buying Pvt. Ltd., Sreeesh Biotech Pvt Ltd., AayurMed Biotech Pvt Ltd., amongst others) and herbal firms (Sajjan Herbomed Promoters, Kapoor Herbal Products, Guru Sharnam Overseas, amongst others) of India. Aloe is present in about 80% of the cosmetics in the European market (CITES 2006).

12. Economics

About Rs. 8000 ($179.96) to 10,000 ($225.00) net profit may be obtained from aloe plantation per hectare in marginal to sub-marginal lands. Financial outlay from India (NABARD 2007) clearly depicts *Aloe* and *Aloe* products as highly lucrative option (Internal Rate of Return >50%) for sustained agriculture, where the Net Present Worth at 15% DF is Rs. 53129.00 ($1194.85)/ha (Maiti and Chandra 2002). The current global turnover of raw Aloe leaves amount up to US$ 70-80 million, which is expected to grow at a rate of 35% in next five years; while processed derivatives and value added products are estimated at around US$ 1 billion and US$ 25 billion, respectively (Das and Chattopadhay 2004). USA supplies the major bulk of Aloe in world (60-65%) followed by Latin American countries (20-25%) and Australia, China and India (10%). It is estimated that about 40-50 thousands rupees may be earned annually from Aloe cultivation. Total production of Aloe in India is estimated to be 1,00,000 tones (MCDGFT 2006).

Chemical constituents

Shelton (1991) in a review reported the presence of anthraquinones (aloin, barbaloin, isobar baloin, anthranol, aloetic acid, anthracene, ester of cinnamic acid, aloe-emodin, emodin, chrysophanic acid, ethered oil, resistannol), inorganic compounds (calcium, sodium, chlorine, manganese, magnesium, zinc, copper, chromium, potassium sorbate), saccharides (cellulose, glucose, mannose, L-rhamnose, aldopentose), enzymes (oxidase, amylase, catalase, lipase, alkaline phosphatase), vitamins (B_1, B_2, B_6, choline, folic acid C, α-tocopherol, β-carotene), essential amino acids (lysine, threonine, valine, methionine, leucine, isoleucine, phenylalanine), nonessential amino acids (histidine, arginine,

hydroxyproline, aspartic acid, glutamic acid, proline, glycerine, alanine, tyrosine) and miscellaneous compounds (cholesterol, triglycerides, steroids, β-sitosterol, lignins, uric acid, gibberellins, lectin-like substances, salicylic acid) in *A. vera*. Gjerstad (1971) found 99.5% water and 0.01% protein in leaves of *A. vera*. Klein and Penneys (1988) suggested that magnesium lactate present in the plant species is known to inhibit histidine decarboxylase thereby preventing the formation of histamine from histidine in mast cells. Waller *et al.* (1978) determined the presence of free amino acids, free monosaccharides and total saccharides upon hydrolysis, sterols and triterpenoids in leaves of the species. Amino acids, D-glucose and D-mannose are reported to be in the water soluble fraction; while, cholesterol, campesterol, β-sitosterol, and lupeol are found in substantial amount in lipid fraction of the leaf extract. Ni *et al.* (2004) following disruption of leaf pulp by homogenization isolated three components by sequential centrifugation and they are thin clear sheets, microparticles and a viscous liquid gel accounting for 16.2, 0.70 and 83.1% of the pulp on a dry weight basis. The carbohydrate composition of each component is distinct; liquid gel contained mannan, microparticle contained glactose-rich polysaccharide(s) and the cell walls are with high level of galactauranic acid (34% w/w).

Presence of flavonoids, terpenoids, lectins (King *et al.* 1995; Eshun and He 2004; Boudreau and Beland 2006), fatty acids, cholesterol (Afzal *et al.* 1991), anthraquinones (free anthraquinones and their derivatives like barbaloin, aloe-emodin-9-anthrone, isobarbaloin, anthrone-C-glycosides – Lorenzetti *et al.* 1964; Sims *et al.* 1971) as well as chromones (8-C-glucosyl-7-*O*-methylaloediol, 8-C-glucosyl-noreugenin, isoaloeresin D, iso rabaichromone, neoaloesin A; Dagne *et al.* 2000; Ni and Tizard 2004), mono- and polysaccharides (pectins, hemicelluloses, glucomannan, acemannan and mannose derivatives; Femenia *et al.* 1999; Choi and Chung 2003), tannins, sterols (lupeol, campesterol and β-sitosterol; Coats and Ahola 2010), salicylic acid, organic acids, enzymes, saponins, vitamins (B_1, B_2, B_{12}, A, C, niacin; Coats 1979), minerals (Na, K, Ca, Mg, Mn, Cu, Zn, Cr and Fe; Newall *et al.* 1996), aloin, anthrone amongst others are also reported by different authors from *A. vera*. Aloe emodin (3-hydroxylmethyl-chrysazin) and aloe lectins are also present in *A. vera* which are antitumor compounds used for the treatment of cancer (Maiti and Chandra 2002). Yang *et al.* (2010) isolated a new triglucosylated naphthalene derivative named aloveroside A along with two known anthraquinone dimers and two 6-phenyl-2-pyrone derivatives from *A. vera* ethanolic extracts.

Aloe products

Commercially *Aloe* may be in the form of pills, sprays, ointments, lotions, liquid, drinks, jellies and creams to name a few of the many products available. The amount of aloe content in products is 20.0% or more in sunburn treatments, 20.0% or more in cream and ointments, 95.0% or more in juice, 50.0% or more in beverages, 10.0% or more in drinks and 5.0% to 10% or more in capsules. Sustainable aloe treatments may provide desirable results.

Therapeutic uses

The species possesses anti-inflammatory (Somboonwong *et al.* 2000; Prabjone e*t al.* 2006; Kohli *et al.* 2011; Park *et al.* 2011), antitumor (Yagi and Takeo 2003; Saini *et al.* 2010), antimetastic (Gribel and Pashinskii 1986), anticytotoxic (Norikura *et al.* 2002), antiproliferative (Kuo *et al.* 2002), antiaging (Danhof 1993), antiulcer (Galal *et al.* 1975; Klein and Penneys 1988; Eamlamnam *et al.* 2006), antituberculosis (Gupta *et al.* 2010), antibacterial (fumaric acid is of potential activity based on mass spectrometry, H-NMR, C-NMR and IR spectral analysis; Agarry *et al.* 2005; Lawrence *et al.* 2009; Bashir *et al.* 2011; He *et al.* 2011; Kohli *et al.* 2011, gel extract; Saritha *et al.* 2010; Sathyaprabha *et al.* 2010), antifungal (methanol and ethanol portions of the leaf extract are more bioactive than ethyl acetate portion and the effect is more pronounced on plant pathogens than human pathogens except *Candida albicans*; Arunkumar and Muthuselvam 2009; Khaing 2011), antidiabetic (Vogler and Ernst 1999) and antioxidant (Saritha *et al.* 2010; Sathyaprabha *et al.* 2010; Khaing 2011) properties apart from its significant uses for wound healing (Fulton 1990; Heggers *et al.* 1993; Udupa *et al.* 1994; Chithra *et al.* 1998; Somboonwong *et al.* 2000; Choi *et al.* 2001; Duansak 2003; Maenthaisong *et al.* 2007; Atiba *et al.* 2011), preventing atheromatous heart disease (Agarwal 1985), protection against skin lesions induced by sulphur mustard (Anshoo *et al.* 2005), controlling sinus disorders, X-ray burns, boils, cold sores and skin infections (Fly and Kiem 1963) as well as diarrhea, electrolyte imbalance, kidney dysfunction, erythema, phytotoxicity (Boudreaua and Belanda 2006), dermatitis (Feily and Namazi 2009), multiple sclerosis (Mirshafiey *et al.* 2010), scabies (Oyelami *et al.* 2009), sepsis (Yun *et al.* 2009) and effective for genital herpes and psoriasis (Syed *et al.* 1996; Vogler and Ernst 1999). *A. vera* also possesses immunosuppressive (Chong *et al.* 1997; Yagi and Takeo 2003), immunomodulator (Ralamboranto *et al.* 1982; Farahnejad *et al.* 2011), scavenging (Yagi *et al.* 2003), chemopreventive (Furukawa *et al.* 2002), microcirculatory (Somboonwong *et al.* 2000), hematoaugmenting (Egger *et al.* 1996), radioprotective (Bakuridze *et al.* 2009) properties amongst others. The species is found to reduce azoxymethane which induce oxidative stress and toxicity in liver (Anilakumar *et al.* 2010) and enhance intestinal absorption and skin permeation (Hamman 2008). Lee *et al.* (1995) reported that dichloromethane extracts of AG is with angiogenic activity. Gel of the species is also used for the treatment of osteoarthritis (Cowan 2010; Maia-Filho *et al.* 2010). Tomasin and Gomez-Marcondes (2011) reported that oral administration of *A. vera* and honey reduces Walker tumor growth by decreasing cell proliferation and increasing apoptosis in tumor tissue.

Amongst potential uses of *A. vera* wound healing activity and antioxidant property are of paramount significance. Wound healing is a highly complex, but orchestrated cascade of events like inflammation, granulation and tissue formation and remodeling of the extracellular matrix, and these events involves cellular phenomena such as migration, proliferation, adhesion, phenotypic differentiation (Raghow 1994). Chithra *et al.* (1988a) reported positive influence on the glycosamino glycan (GAG) components of the matrix as well as elevated levels of hyaluronic acid and dermatan sulphate in a healing wound. Chithra *et al.* (1988b) also suggested that AG influences collagen content of the granulation tissue and the degree of cross linking, promoting wound healing. Glycoprotein molecule in AG (possesses cell proliferation boosting activity; 29 kDa fraction; Yagi *et al.* 1997; 5.5 kDa, G1G1M1DI2; Choi *et al.* 2001), mannose 6-phosphate (cell proliferation in mice fibroblast through growth receptors; Davis *et al.* 1994; mannose 6-phosphate linked to a insulin like growth factor 11 receptor protein; Morgan *et al.* 1987), acemannan (through macrophage activation; Zhang and Tizard 1996; 2-16 mg/ml significantly stimulate keratinocyte growth factor I, vascular endothelial growth factor and type I collagen expression; Jettanacheawchankit 2009), macrophages stimulation by AG which in turn triggers chemical messengers inducing fibroblast (Tizard *et al.* 1994), presence of vitamin D in gel (Mackee 1938) along with vitamin C, vitamin B complex and zinc (Datta Gupta 2010) are important in wound healing activities.

Phenolic anthraquinones of AG containing aloin, aloe-emodin, barbaloin and emodin are scavenging reactive oxygen species (Malterud *et al.* 1993; Yen *et al.* 2000). Lee *et al.* (2000) isolated and identified a compound as 8-C-β-D-[2-*O*-(E)-coumaroyl]glucopyraosyl11-2-[2-hydroxyl]-propyl-7-methoxy-5-methylchromone comparable to α-tocopherol from lyophilized AG possessing antioxidant potentiality. Isorabaichrrome along with feruloylalosein and p-coumaroy-laloesin (aloesin derivatives; Yagi *et al.* 1997,

1999), dihydrocoumarin derivatives (Zhang *et al.* 2006), polysaccharide APS-1 (mannose and glucose 18:5, molweight 2.1×10^5 Da; Wu *et al.* 2006), polysaccharide fractions GAPS-1 and SAPS-1 (isolated from parenchymatous gel and from leaf skin following ion-exchange chromatography and gel chromatographic technique after irrigating the plants with sea water for 3.5 years; Liu *et al.* 2007), aloe-emodin as well as glycosylchromone aloresin B (extracted from dried flowers; Keyhanian and Stahl-Biskup 2007) are potent component of *A. vera* to possess free radical-scavenging activities. Sultana *et al.* (2009) reported AG extracted from supercritical carbon dioxide (33.5%), and solvent (39.7%) extraction methods yielded higher free radical scavenging activity; although ethanol extraction shows 14.2% activity. The chloroform-ethanol and hexane extracts of *A. vera* leaf skin are found to show maximum antioxidant activity.

Other potential uses

George *et al.* (2009) compared the antimicrobial effectiveness of *A. vera* tooth gel with two popular, commercially available dentifrices (Pepsodent-Unilever, Englewoodcliffs, NJ:201.894.7660; Colgate-Colgate-Palmolive, Canton MA:800.821.2880) and the result showed that *A. vera* gel and the toothpastes are equally effective against *Candida albicans*, *Streptococcus mutans*, *Lactobacillus acidophilus*, *Enterococcus faecalis*, *Prevotella intermedia* and *Peptostreptococcus anaerobius* and the gel is more effective than toothpastes against *S. mitis*. Gupta Datta (2010) conducted a review exploring cosmetic potential of AG in relation to wound healing, antioxidant and UV-opacity. UV-opacity of AG is also studied by Kumar *et al.* (2009). Rodríguez *et al.* (2010) reported the significance of the species as a functional ingredient in foods. Madan and Singh (2010) formulated AG using polymers like HPMC, Carbopol 934P, methylcellulose and sodium alginate using various physiochemical parameters like pH, viscosity, drug content and spreadability including *in vitro* permeation studies through cellulose membrane and antimicrobial activity and recommended that formulations prepared using Carbopol 1934P possesses desired properties and exhibited better release pattern.

Bioavailability

Vinson *et al.* (2005) described the effect of consumption of *A. vera* liquid preparations on the absorption of water- or fat-soluble vitamins. The plasma bioavailability of vitamin C and E are determined in normal fasting subjects (eight subjects for vitamin C and ten for vitamin E; subjects consumed either 500 mg of ascorbic acid or 420 mg of vitamin E acetate alone as control or combined with 2 oz of two different *Aloe* preparations – leaf extract or inner fillet gel). Blood collected (periodically up to 24 h after consumption) is analyzed for ascorbate and tocopherol by HPLC with UV detection. Results indicated (on comparative basis: control area 100%, *Aloe* gel area 304% and *Aloe* whole leaf 80% in plasma ascorbate after 8 and 24 h; for vitamin E – control 100%, gel 369% and leaf 198%) that aloes improve the absorption of both vitamin C and E and therefore *Aloe* may be considered as a good complement to vitamins.

Cole and Heard (2007) studied (*in vitro*) *A. vera* juice as a skin permeation enhancer for some drugs (caffeine, colchicine, mefenamic acid, oxybutynin and quinine). Experiments conducted revealed that colchicine, oxybutynin and quinine showed permeation enhancement ($P \leq 0.05$) in the presence of *A. vera* (ear skin); however, enhancement potential is dependent upon the molecular weight of the drug in formulation. Enhancement effect is attributed to yet unidentified component(s) within *A. vera*.

Takahashi *et al.* (2009) encapsulated AGE (*Aloe vera* leaf gel extracts) with liposomes (prepared from soyabean lecithin – SLP-WHITE, 1.0 wt% by the Bangham as well as mechanochemical methods for good trapping efficiency up to the AGE of 0.5 wt%) to enhance the bioavailability of AGE. The encapsulated AGE is examined for the effects on proliferation and type I collagen synthesis in normal human neonatal skin fibroblasts, NBIRGB cells and it clearly shows that liposomal AGE significantly increase the collagen synthesis by 23%, while AGE alone possesses a small effect. Further, liposomal AGE is studied on proliferation in normal human epidermal keratinocytes, NHEK(F) cells and it is found that encapsulated AGE (4 and 20 mg/ml of the extract showed 77 and 101% proliferation rate, respectively) with enhance activity than AGE alone (4 and 20 mg/ml extract demonstrated 41 and 60%, respectively). Thus, it may be inferred that the bioavailability and skin care properties of AGE enhance by liposome encapsulation.

Yun *et al.* (2010) examined the effect of two different *A. vera* preparations (aloe inner leaf gel – AG and aloe whole leaf decolorized gel – AL) compared to placebo on the bioavailability of vitamins C and B_{12} in healthy human volunteers in a randomized cross over trials. Subjects (n = 15) received in a random fashion either aloe whole leaf extract (AL with vitamin B_{12}, 1 mg and vitamin C 500 mg) or aloe fillet gel (AG with B_{12} 1 mg and vitamin C 500 mg) or water (with B_{12}, 1 mg and C with 500 mg), and fasting blood obtained from 1, 2, 4, 6, 8 and 24 h postingestion of aloe/water is being studied. Results indicated that both aloes significantly ($P < 0.01$) enhanced plasma oxygen radical absorbance capacity – ORAC (AG – 4 and 24 h, AL – 4 h), plasma vitamin C (AG – 4, 6, 8 and 24 hrs, AL – 4 and 6 h) and serum B_{12} level (1 and 2 h) in comparison to baseline and placebo, thereby indicating that both AG and AL preparations are safe, well tolerated, and elevate the bioavailability of vitamin C and B_{12} and antioxidant potential.

Edible coating

Valverde *et al.* (2005) reported a novel edible coating based on *A. vera* gel (SP patent filed 200302937) as a means of preservation to maintain the quality, enhancing self life and safety of cv. 'Crimson' seedless table grapes. Uncoated cluster showed a rapid deterioration with an estimated self-life period of 7 days at 1°C plus 4 days at 20°C but *A. vera* gel significantly delayed post harvest quality losses, and storability may be extended up to 35 days at 1°C. Serrano *et al.* (2006) also reported the use of *A. vera* gel coating in preservation and restoring functional properties of table grapes. Dang *et al.* (2008) studied the effect of different edible coatings (aqueous mango carnauba 1:1 v/v, Semperfresh 0.6%, *A. vera* gel 1:1 v/v, *A. vera* gel 100%) on mango fruit ripening. Ripe fruit quality parameters included color, firmness, soluble solids concentrations, total acidity, ascorbic acid, total carotenoids, fatty acids and aroma volatiles and results suggested that mango carnuba is most effective while, Semperfresh and *A. vera* gel (1:1 or 100%) slightly delayed fruit ripening but reduced fruit aroma volatile development.

Clinical trials

Syed *et al.* (1996) studied the efficacy and tolerability of tropical *A. vera* extract 0.5% in a hydrophilic cream to cure patients with psoriasis vulgaris (60 patients, 36 M/24 F, aged 18-50 years; 3 times daily for 5 consecutive days, maximum 4 weeks active treatment) and the results obtained were positive (aloe vera extract cream – cured 25/30, 83.3%; placebo cure rat – 2/30, 6.6%, $P < 0.001$; resulting in significant clearing of the psoriatic plaques – 328/396, 82.8% vs placebo 28/366, 7.7%, $P < 0.001$). Ikeno *et al.* (2002) suggested that life-long *A. vera* ingestion does not cause any obvious harmful and deleterious side effect (male specific pathogen free Fischer 344 rats are experimented, grouped – A: control, semi-synthetic diet with *A. vera*; B: fed with 1% freeze dried *A. vera* filet; C: fed with 1% charcoal processed, freeze-dried *A. vera* filet; D: control diet along with charcoal processed whole leaf – 0.02% in drinking water), and could also be beneficial for the prevention

of age related pathology. Heggie *et al.* (2002) reported that aqueous cream of the species is useful in reducing dry desquamation and pain related to radiation therapy (experiment conducted with 225 patients with breast cancer after lumpectomy or partial mastectomy and who required a course radiation therapy; *A. vera* gel or tropical aqueous cream is applied 3 times per day throughout and for 2 weeks after radiation treatment). Kodym *et al.* (2003) reported that eye drops containing aqueous extract of fresh leaves of aloe, boric acid, thiomersal, sodium pyrosulphite, disodium EDTA, betaphenylethyl alcohol and neomycin sulphate, both freshly prepared and after 2 years of storage, met the requirements of the Polish Pharmacopoeia. Kosif *et al.* (2008) administered *A. vera* gel to female Wistar albino rats and on microscopic examination of placenta revealed that its structure made a possible compensatory adjustment to maintain adequate metabolic exchanges. Result also indicated that exposure of Aloe gel during pregnancy did not led to fetal growth retardation, fetal death, abortion or teratogenic effect. Maurya *et al.* (2008) reported potential larvicidal activity of *A. vera* (methanolic extract) and considered to be an ecofriendly alternative in the management of *Culex quinquefasciatus* (filariasis vector). Chen *et al.* (2009) reported AG and whole leaf extract significantly reduce the transepithelial electrical resistance of the Caco-2 cell monolayers (concentration above 0.5% w/v) thereby suggesting the ability to open tight junctions between adjacent cells and the effect is fully reversible, while gel and leaf extract solution are found to enhance the transport of insulin across the caco-2 cell monolayers compared with the control. Cho *et al.* (2009) studied the effect of AG on the clinical signs and biochemical changes of aging skin (30 healthy female over the age of 45 are given 2 different doses – 1,200 mg/d for 90 days) and it is noted that it improves facial wrinkles and elasticity and it increases the type 1 procollagen gene expression in human skin *in vivo*. Tamura *et al.* (2009) suggested that aloe sample (tested on BALB/c mice) inhibit infectious (elimination of *E. coli*, K-12 strain from peritoneal cavity within 48 h of infection) disease by stimulating the host defense mechanism, especially the phagocytes. Patil (2010) studied the efficacy of crude *A. vera* leaf gel in protecting hepatic cells (*in vitro* rat liver slice model is used in investigation) against oxidative stress mediated by varying concentrations of APAP (N-acetyl para amino phenol) or AAP (acetaminophen) during different period of time. Results indicated that AG is protective against toxicity induced by APAP or AAP (AST – aspartate transaminase, ALT – alanine transaminase, ALP – alkaline phosphatase – are used as markers of hepatocyte damage along with glutathione and TBARS – thiobarbituric acid reactive substances). Saini *et al.* (2010) reported AG/ extract protects mice against 7,12-dimethylbenz(a)anthracxcene – DMBA/croton oil-induced skin papillomagenesis and it is likely due to the chemopreventive activity of high concentrations of antioxidant such as vitamin A, C and E; glutathione peroxidase, several isozymes of superoxide dismutase, the minerals selenium and zinc and polysaccharides present in the species. Salazar-Sánchez *et al.* (2010) reported that application of *A. vera* improves the total quality of life scores in patients (64 patients with OLP – oral lichen planus were studied of which 32 were randomized in a double-blind study to either *A. vera* or placebo; dose 0.4 ml, 3 times a day) with OLP. Shah *et al.* (2010) from their studies on 16 participants (age group 25 ± 5 years) suggested that a single dose of oral *A. vera* had no effect on electrocardiographic or blood pressure (maximum systolic blood pressure – placebo and aloe-treated 120 ± 16 and 120 ± 14 ms, respectively; maximum diastolic – placebo and aloe-treated 74 ± 10 and 75 ± 9 ms, respectively) measurements. Chavhan *et al.* (2011) conducted experiments on rat to examine the effect of *A. vera* juice (2.5% in drinking water) on the clinical signs, hematological, biochemical and histopathological changes in vitamin D(3) toxicity at a dose rate 2 mg.kg b/wt. and it showed no protective effect on vitamin D(3) toxicity. Kumar *et al.* (2011) evaluated the hupoglycemic activity of aloe extract on streptozotocin-induced diabetic mice (dosage - 130 mg/kg body weight per day for 4 weeks) and found significant decrease in blood glucose and total cholesterol. Lyophilized aqueous aloe extract (1 mg/ml) upregulated the GLUT-4 mRNA synthesis in mouse embryonic NH/3TC cells. Shin *et al.* (2011) reported that dietary aloe improves insulin sensitivity via the suppression of obesity-induced inflammation in obese mice.

Precautions

Aloe product used internally may cause irregular heart beat. It is medically advised to avoid aloe preparations during pregnancy or menstruation. Aloe products may cause painful cramping. Yang *et al.* (2010) from clinical trial experiments suggested that *Aloe* should be considered as a causative agent in hepatotoxicity.

Cytogenetic aspects

1. Chromosomal studies

Vig (1968) observed spontaneous chromosome abnormalities like 2n=10 chromosomes rather than 2n=14 in root system of *A. vera* plant; however, the missing chromosomes could not be recognized. Pollen mother cells (PMCs) of the plant are with regular 2n=14 chromosomes but meiotic anomalies like asynapsis, lagging chromosomes, bridges with or without fragments and delayed disjunction of some bivalents are also studied. Wang *et al.* (1998) reported 2n=14 chromosomes in *A. vera* L. var. *chinensis* (Han) Berger and the karyotype showed 6 subtelocentric and 8 submedian chromosomes of which 4 long and 3 short pairs are observed. Alam and Khanam (2005) made fluorescent karyotype analysis of *A. vera* including *A. zebrina*, *A. abyssinica* and *A. indica* and reported diversification in relation to CMA and DAPI banding properties. The species showed 2n=14 chromosomes with 8 large and 6 small. *A. vera* showed 3 CMA-negative and 10 DAPI positive bands. AT rich is 6.3 μm in the species and it is directly proportional to the number of bands. Imery-Buiza *et al.* (2008) studied karyotypes of *A. saponaria* (2n=2x=14, 8 long (L) + 6 short (S) chromosomes), *A. vera* (2n=4x=28, 16L + 12S) and experimentally induced triploid between the species (2n= 3x=21, 12L + 9S). The triploid karyotype showed absence or addition of small chromosomes, terminal deletion of variable sizes leading to the formation of atypical chromosomes, or the loss of a long chromosome. Imery-Buiza (2007) noted karyological instability during pollen mother cells formation in *A. vera*. Gunjan and Roy (2010) assessed karyotype asymmetry/symmetry of 3 species of *Aloe* i.e. *A. vera*, *A. indica* and *A. ferox* by eight different methods and suggested karyotype asymmetry in chromosome sets, and compared to related taxa a relationship is being drawn. Das *et al.* (2011) performed comparative karyomorphological analysis of *in vitro* and *in vivo* grown plants of *A. vera* and reported 2n=14 chromosomes which resolved into 7 bivalents during meiosis. Percentage of pollen viability is high in both cases yet the flowers failed to form fruits. Pollen mitosis is used to prepare haploid karyotypes.

2. Male sterility

Keijzer and Cresti (1987) studied cytological differences between the anther development of a male sterile (*A. vera*) and a male fertile (*A. ciliaris*) *Aloe* species to explain interactions between anther tissues, and reported that deviation in the layers of the locule wall and the microspores of the male sterile anther are related to each other.

Molecular aspects

Adams *et al.* (2000) reported that though there exist striking stability of karyotype structure and location of 5S rDNA in *Aloe* taxa, the distribution of 18S-5.8S-26S rDNA (physical

organization is assessed in 13 species using fluorescent *in situ* hybridization (FISH) and compared with a phylogenetic tree of 28 species constructed by sequence analysis of the internal transcribed spacer; ITS) is not so constrained and found to change during *Aloe* speciation. Yu *et al.* (2002) suggested that *A. vera* is involved in the differentiation of CD^{4+} lymphocytes by means of regulating the expression of Th1 and Th2 cytokines (ovalbumin sensitized white rat are used as animal models). Darokar *et al.* (2003) suggested that *A. vera* is closely related to *A. perryi* based on DNA comparison studies. Hiroko *et al.* (2003) distinguished four *Aloe* species (*A. vera*, *A. ferox*, *A. africana* and *A. arborescens*) by RAPD (32 different 10-mer primers are examined; the products of PCR are analysed in agarose gel) analysis with the view to identify the botanical species of Aloe in commercial food products. Sun *et al.* (2003) studied the induced expression of gene for NADP-malic enzymes in leaves in *A. vera* under salt stress. Treutlein *et al.* (2003) using chloroplast DNA sequence comparison and ISSR profiling, suggested that *A. vera* is closely related to *A. forbesii*, *A. inermis*, *A. scobinifolia*, *A. sinkatana* and *A. striata.* Campestrini *et al.* (2006) focused on the development of a cloning protocol to provide propagation material with superior quality to the private sector in Southern Brazil, and such a biotechnological approach afforded 4,300 plantlets from 20 explants over a 6-month period. Yagi *et al.* (2006) adopted the ITS I region of rDNA as a molecular marker for differentiating *A. vera* plants from geographically distributed and clonally regenerated *A. vera* plants (clonally regenerated *A. vera* and the same species in Japan, USA and Egypt revealed 252 and 254 bps respectively), and it is suggested that the base peak substitution in the ITS I region may arise from the different nutritional and environmental factors in cultivation and plant growth stages. Wang and He (2007) reported a new cold-induced dehydration responsive element-binding (DREB) gene encoding an Ap2/ethylene response element binding protein transcription factor from *A. vera* by rapid amplification of complementary DNA ends (RACE). The deduced protein contained a putative acidic activation domain and an AP2 DNA binding domain of 64 amino acids. The expression analysis showed that the transcript accumulated rapidly under cold stress and peaked at 12 h, then decreased to the original level. Govinden-Soulange *et al.* (2007) reported genetic closeness of *Lomatophyllum* species and *A. vera* following RAPD-PCR. He *et al.* (2007) performed genetic transformation of *A. vera* by *Agrobacterium tumefaciens* (strains used: EHA105 and C58C1). G418-resistant plantlets are generated and Southern blotting, PCR and ELISA analysis indicated that the GUS gene (transient expression in stem explant with 80 and 30% potential in EHA105 and C58C1 strains, respectively of *A. tumefaciens*) is successfully transferred into *Aloe* and the methodology may effectively be utilized for genetic improvement. Lin *et al.* (2007) suggested that aloe-emodin metabolites decreased NMDA (N-methyl-D-aspartic acid) induced apoptosis of RGCs (retina ganglion cells) by preserving and inducing (proteins of control, NMDA group and aloe-emodin cotreated group are separated by 2-D gel electrophoresis, protein spots are excised and analyzed by nano-liquid chromatography with mass spectrometry, tandem MS) some proteins related to the antioxidation and regulation of cells energy. Both the level of RNA and protein of superoxide dismutase (Cu-Zn) are significantly elevated after aloe-emodin metabolites are added. Qian *et al.* (2009) reported a new gene encoding protein DREB from *A. vera* via combined method of PCR and 3´RACE and based on homology of previously reported AIDREB1, the gene (Gene Bank accession number FJ560 460) is named as AIDREB2. RT-PCR revealed that expression of AIDRER2 is significantly induced by ABA and dehydration treatment (salt or PEG 600) as well as upregulated by cold stress and external ethylene. Hua *et al.* (2009) raised transgenic aloe plants mediated by *Agrobacterium* with TaDREB gene from wheat, which showed tolerance to low temperature. Velcheva *et al.* (2010) bombarded calluses with a plasmid containing *uid*A and *hpt* genes under the control 35S promoter and the transformed shoots are regenerated under stepwise selection in hygromycin containing liquid medium supplemented with different oxidants. Amberlite XAD-4 resin is embedded into alginate beads and added to the selection medium. The transgenic nature of the regenerated plants is verified by histochemical GUS assay and Southern blot hybridization.

BIOTECHNOLOGY

Callus induction

Cavallini *et al.* (1993) studied chromosome number of six plants of *A. vera* regenerated from callus and found one tetraploid. Cytophotometric analysis of Feulgen-stained early prophase nuclei showed a 22.5% basic DNA content variation among diploid plants. Ribosomal DNA content also varied in regenerated plants. Wang *et al.* (2004) determined aloin content in callus of *A. vera* var. *chinensis* following HPLC and TLC. On MS medium with 1 mg/l 1-naphthalene acetic acid (NAA) + 0.5 mg/l 6-benzyladenine (BA) callus obtained from leaf contained the most aloin, while it is low in the callus from stem. There is no aloin in callus from roots. During callus differentiation, irrespective of the explants used, aloin content is low.

Micropropagation

Natali *et al.* (1990) reported rapid and effective micropropagation of *A. vera* from vegetative meristems. Micropropagation is achieved on medium containing 1.1 µM 2,4-dichlorophenoxy acetic acid (2,4-D) and 2.3 µM kinetin (Kin) for 15-30 days. High morphogenetic ability is maintained by transferring explants (vegetative meristems) after 60 days onto medium containing 0.11 µM 2,4-D and 2.2 µM BA. Meyer and van Staden (1991) reported that axillary bud development and adventitious bud formation are obtained with decapitated shoot on a MS medium supplemented with 5 µM indole-3-butyric acid (IBA) or (indole-3-acetic acid) IAA (optimal sucrose concentration 3%, temperature > 10°C < 30°C). Morphogenesis is inhibited by 2,4-D, BA and thidiazuron. Roy and Sarkar (1991) induced best callus formation using young axillary buds on Murashige and Skoog (MS) medium supplemented with 1 mg/l 2,4-D and 0.2 mg/l Kin. The use of polyvinylpyrrolidone (PVP) in the nutrient media reduced the secretion of phenolic substances from explants. Shoots initiated from callus when 2,4-D concentration is reduced and Kin is increased. Baksha *et al.* (2005) reported multiple shoot (10/explant) formation from shoot tip explants (cultured on MS + 2.0 mg/l BA + 0.5 mg/l NAA). About 95.0% rooting is obtained from microshoots cultured on ½ MS + 0.5 mg/l NAA, and the rooted plantlets are transferred to soil with 70.0% survival. Ahmed *et al.* (2007) developed an efficient (using shoot tip explant) micropropagation method: shoot proliferation medium: MS + 2.0 mg/l BA + 0.5 mg/l Kin + 0.2 mg/l NAA – 96.0% of shoots are proliferated; adventitious rooting: MS + 0.2 mg/l NAA + 0.5 mg/l NAA – 80.25% rooting and highest number of roots/culture is 6.71. Rooted shoots (20-days-old) transplanted into a mixture of garden soil, compost and sand (2:1:1) and 80.0% survival is achieved after 5 weeks and following acclimatization, the survival rate is 82.0%. Hosseini and Parsa (2007) reported the best media composition for micropropagation to be MS + 1 mg/l Kin + 0.1 mg/l IAA and the produced plantlets rooted in hormone-free MS medium; on transferring to soil 83.0% survived. Hashem Abadi and Kaviani (2008) reported a rapid micropropagation protocol (MS basal media supplemented with different concentrations of BA and NAA) using shoot tips as explants; after 8 weeks best proliferation of shoots/explant is 9.67 and successful rooting is achieved on MS medium supplemented with 0.5 mg/l BA + 0.5 mg/l NAA. The rooted plantlets are acclimatized in plastic pots containing a mixture of cocopeat and perlite (1:1) and showed 95.0% sur-

vival. de Oliveira (2009) proposed a protocol for large-scale *A. vera* production using the micropropagation of apical buds (MS + 2 mg/l BA; during 120 days 136 green apical shoots bearing axillary buds multiplied four times at 30-day intervals in the same MS medium, re-inoculating 7 to 9 explants per flask each time). Shoot elongation and rooting are carried out in the same MS medium without BA and a total of 40,495 microplants are obtained, a yield of 300 microplants/apical bud at a rate of 1:5.3 with every multiplication period of 30 days. *A. vera* microplants are successfully acclimatized after transferring to 36- and 64-cell polyethylene trays containing proper substrate under *ex vitro* greenhouse conditions. Hashem Abadi and Kaviani (2010) proposed a production technique in *A. vera* using shoot tips as explant. Explants cultured in MS supplemented with BA (0.5 mg/l) and NAA (0.5 mg/l) induced best proliferation (9.67) and rooting with IBA (0.5 mg/l) and NAA (1.0 mg/l). The regenerated plants are transferred to cocopeat and perlite (1:1) after hardening they showed 100% of survival. Nayanakantha *et al.* (2010) also reported an efficient micropropagation protocol using lateral shoot explants. Both shoot induction and elongation are found to be better on MS + 4 mg/l BA + 0.2 mg/l NAA + 1 g/l PVP, and the cultures showed 16 shoot/explants. Adventitious buds formation (21.5 shoots/explant) is noted in MS + 4 mg/l BA + 0.2 mg/l NAA + 1 g/l PVP + 10 mg/l citric acid + 0.5 g/l activated charcoal, further elongation and rooting of microshoots are obtained when sub-cultured on to MS + 0.5 g/l activated charcoal. Rooted plantlets showed 100% survival after acclimatization. Rathore *et al.* (2011) defined a regeneration system for mass scale propagation (MS based medium supplemented with different plant growth hormones at different concentrations with 4% carbohydrate and activated charcoal as additive sources for callus development and shoot bud formation; a regenerated callus developed plantlets in MS supplemented with 6-BA and additives) of a selected genotype of *A. vera* (sweet aloe).

CONCLUSION

A comprehensive overview on *A. vera* is presented in the text with an objective of providing unabridged repository of references to present and future researchers for profitable utilization of the plant species, and human welfare. Further, genetic improvement (enhancement in leaf yield and quality improvement of aloe products) in the species by widening the gene pool through conventional (induced mutagenesis) and non-conventional (biotechnological approaches) methods is of utmost necessity (the species is clonally propagated, and it may be of advantage for screening suitable genetic variations) to meet up the upsurging demand of the species (value added products) in National and International markets.

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